# CHAPTER 5

# INTERIOR WIRING

## INTRODUCTION

This chapter will help you understand the principles of interior wiring. The requirements for installing electrical systems are found in the current edition of the *National Electrical Code*® (NEC®). The requirements are specific and detailed, and they change somewhat as the complexity of the system increases. Therefore, the Code should be checked for proper installation of electrical systems.

## INTERIOR SYSTEMS BELOW GRADE

An electrical system that is installed in concrete or in direct contact with the earth is considered to be a system below grade.

Below grade conduit layout and direct buried cable or other raceways must be installed to meet the minimum cover requirements of table 5-1. Under buildings, underground cables must be in a raceway that is extended beyond the outside walk of the building. Direct buried cables emerging from the ground will be in protected enclosures or raceways extending from the minimum cover distance, required by table 5-1, below grade to a point at least 8 feet above finished grade. There is no requirement for the protection of direct buried cables in excess of 18 inches below the finished grade.

Conduit in concrete buildings can be installed while the building is being erected. The outlets should be attached to the forms, and the conduits between outlets should be attached to reinforcing steel with metal tie wires so that the concrete can be poured around them. When several conduits pass through a wall, partition, or floor, a plugged sheet-metal tube should be set in the forms to provide a hole for them in the concrete. When a single conduit passes through a wall, partition or floor, a nipple or a plugged sheet-metal tube can be set in the forms.

Ferrous or nonferrous metal raceways, cable armor, boxes, cable sheathing, cabinets, elbows, couplings, fittings, supports, and support hardware may be installed below grade. These materials also may be installed in areas subject to severe corrosive influences when made of material judged suitable for the condition or when provided with corrosion protection approved for the condition.

## WET AND CORROSIVE INSTALLATIONS

Underground-feeder cable and branch-circuit cable provide an economical wiring system for wet and corrosive installations. Type UF two-conductor cable resembles Type USE service-entrance cable in general appearance. The insulation is a plastic compound. NEC® statements with respect to its use are as follows: Underground-feeder and branch-circuit cable may be used underground, including direct burial in the earth, as feeder or branch-circuit cable when provided with overcurrent protection not in excess of the rated current-carrying capacity of the individual conductors. If single-conductor cables are installed, all cables of the feeder circuit, subfeeder circuit, or branch circuit, including the neutral and equipment grounding conductor, if any, will be run together in the same trench or raceway. If the cable is buried directly in the earth, the minimum burial depth permitted is 24 inches if the cable is unprotected and 18 inches when a supplemental covering, such as a 2-inch concrete pad, metal raceway, pipe, or other suitable protection, is provided. Type UF cable may be used for interior wiring in wet, dry, or corrosive locations under the recognized wiring methods of the Code, and when installed as a nonmetallic-sheathed cable, it will conform with the provisions of the Code and be of a multiconductor type. Type UF cable also must be of a multiconductor type if installed in a cable tray.

Type UF cable will not be used (1) as service-entrance cable, (2) in commercial garages, (3) in theaters, (4) in motion-picture studios, (5) in storage-battery rooms, (6) in hoistways, (7) in any hazardous location, (8) embedded in poured cement, concrete, or aggregate except as provided in the Code, and (9) where exposed to direct rays of the sun unless identified as sunlight-resistant.

## MARKINGS

Ungrounded conductors are available as single or multiconductor cables. These cables are clearly marked to identify them as grounded and grounding

**Table 5-1.—Minimum Cover Requirements for 0 to 600 Volts (Burial in Inches)**

**Minimum Cover Requirements, 0 to 600 Volts,**
Burial in Inches

Cover is defined as the shortest distance measured between a point on the top surface of any direct-buried conductor, cable, conduit or other raceway and the top surface of finished grade, concrete, or similar cover.

| Location of Wiring Method or Circuit | Type of Wiring Method or Circuit | | | | |
|---|---|---|---|---|---|
| | See Note 1<br>Direct Burial Cables or Conductors | See Note 2<br>Rigid Metal Conduit or Intermediate Metal Conduit | See Note 3<br>Rigid Nonmetallic Conduit Approved for Direct Burial Without Concrete Encasement or Other Approved Raceways | See Note 4<br>Residential Branch Circuits Rated 120 Volts or Less with GFCI Protection and Maximum Overcurrent Protection of 20 Amperes | See Note 5<br>Circuits for Control of Irrigation and Landscape Lighting Limited to Not More than 30 Volts and Installed with Type UF or in Other Identified Cable or Raceway |
| All locations not specified below | 24 | 6 | 18 | 12 | 6 |
| In trench below 2-inch thick concrete or equivalent | 18 | 6 | 12 | 6 | 6 |
| Under a building | In raceway only | Not used | Not used | In raceway only | In raceway only |
| Under minimum of 4-inch concrete exterior slab with vehicular traffic and the slab extends not less than 6 inches beyond the underground installation | 18 | 4 | 4 | 4 inches for raceway and 6 inches for direct burial | 4 inches for raceway and 6 inches for direct burial |
| Under Streets. highways, roads, alleys, driveways. and parking lots | 24 | 24 | 24 | 24 | 24 |
| One and two family dwelling driveways, parking areas. and other purposes | 18 | 18 | 18 | 12 | 18 |
| In or under airport runways including adjacent areas where trespassingprohibited | 18 | 18 | 18 | 18 | 18 |

Table 5-1.—Minimum Cover Requirements for 0 to 600 Volts (Burial in Inches)—Continued

| | | | | | |
|---|---|---|---|---|---|
| In solid rock where covered by minimum of 2 inches concrete extending down to rock | 2 inches, raceway only | 2 | 2 | 2 inches, raceway only | 2 inches, raceway only |

Note 1. For SI units; one inch = 25.4 millimeters.

Note 2. Raceways approved for burial only where concrete encased will require concrete envelope not less than 2 inches thick.

Note 3. Lesser depths are permitted where cables and conductors rise for terminations or splices or where access is otherwise required.

Note 4. Where one of the conduit types listed in columns 1 through 3 is combined with one of the circuit types in columns 4 and 5, the shallower depth of burial is permitted.

conductors. Ungrounded conductors will be distinguished by colors other than white, natural gray, or green, or by a combination of color plus distinguishing marking. Distinguishing markings also will be in a color other than white, natural gray, or green. and will consist of a stripe or stripes or a regularly spaced series of identical marks. Distinguishing markings will not conflict in any manner with the surface markings required by the NEC®.

## UNDERFLOOR RACEWAY SYSTEMS

Underfloor raceway systems are used in office buildings for the installation of the wiring for telephone and signal systems and for convenience outlets for electrically operated office machinery. They provide a flexible system by which the location of outlets may be changed easily to accommodate the rearrangement of furniture and partitions. The NEC® allows their use when embedded in concrete or in the concrete fill of floors. Their installation is allowed only in locations that are free from corrosive or hazardous conditions. No wires larger than the maximum size approved for the particular raceway will be installed. The voltage of the system must not exceed 600 volts. The total cross-sectional area of all conductors in a duct must not be greater than 40 percent of the interior cross-sectional area of the duct.

An underfloor raceway system consists of ducts laid below the surface of the floor and interconnected by means of special cast-iron floor junction boxes. The ducts for underfloor raceway systems are made of either fiber or steel. Fiber ducts are made in two types-the open-bottom type and the completely enclosing type. Steel ducts are always of the completely enclosing type, usually having a rectangular cross section. In the underfloor raceway system, provision is made for outlets by means of specially designed floor-outlet fittings that are screwed into the walls of the ducts. When fiber ducts are used, the duct system is laid in the floor with or without openings or inserts for outlets. After the floor has been poured and finished as desired, the outlet fittings are installed into inserts or at any points along the ducts at which outlets are required. The method of installing outlet fittings is described in the next paragraph. When steel ducts are used, provision for the outlet fittings must be made at the time that the ducts are laid before the floor or floor fill is poured. The steel ducts are manufactured with threaded openings for outlet connections at regularly spaced intervals along the duct. During the installation of the raceway and the floor, these outlet openings are closed with specially constructed plugs whose height can be adjusted to suit the floor level. For telephone and similar circuits, much wider ducts can be obtained.

In general, underfloor raceways should be installed so that there is at least 3/4 inch of concrete or wood over the highest point of the ducts. However, in office-approved raceways, they may be laid flush with the concrete if covered with linoleum or equivalent floor covering. When two or three raceways are installed flush with the concrete, they must be contiguous with each other and joined to form a rigid assembly. Flat-top ducts over 4 inches wide but not over 8 inches, spaced less than 1 inch apart, must be covered with at least 1/2 inch of concrete. It is standard practice to allow 3/4-inch clearance between ducts run side by side. The center line of the ducts should form a straight line between junction boxes. If the spacing between raceways is 1 inch or more, the raceway may be covered with only 1 inch of concrete. All the joints in the raceway between sections of ducts and at junction boxes should be made waterproof and have good electrical contact so that the raceways will be electrically continuous. Metal raceways must be properly grounded.

To establish outlets in a preset system after the finish is in place, you have to determine the location of the insert. Inserts can be located by using an insert finder. Once inserts are located, the flooring is chipped down to expose the insert cap. The cap is removed and a hole cut in the duct so the wires can be fished through and connected to the receptacle.

The following procedures should be used to install an outlet fitting at any point in a completely enclosed underfloor fiber raceway:

1. Locate the duct line.
2. Cut a hole in linoleum or other floor covering.
3. Chip a hole down to duct.
4. Cut a hole in the duct.
5. Screw insert into the. duct.
6. Anchor the insert with grouting compound.
7. Screw the outlet into the insert.

The special tools, provided by the manufacturer, for this purpose should be used to ensure satisfactory workmanship.

Combination junction boxes accommodating the two or three ducts of multiple-duct systems may be used, provided separate compartments are furnished in the boxes for each system. It is best to keep the same relative location of compartments for the respective systems throughout the installation.

All the joints in or taps to the conductors must be made in the junction boxes. No joints or taps should be made in the ducts of the raceway or at outlet insert points.

## INTERIOR SYSTEMS ABOVE GRADE

An interior system above grade starts at the service drop and covers all the conduit layouts (excluding in-the-slab), communication, power, and lighting circuits. You must be aware of the NEC® rules that govern industrial and residential interior electrical systems. To gain additional knowledge, you may read the following: *Standard Handbook for Electrical Engineers* and the *American Electrician's Handbook.*

## CONDUIT LAYOUT

Follow the construction blueprints and specification when laying out conduit runs. Remember, most prints will not show the direction of the conduit run. They only direct you to install a circuit from the distribution panel to a location where a electrical apparatus will be serviced. When you install any circuit, complete the service installation with the shortest route possible.

Properly bent conduit turns look better than elbows and, therefore, are preferable for exposed work (fig. 5-1). If bends are formed to a chalk line, draw the chalk line as suggested in figure 5-2. The conduits can

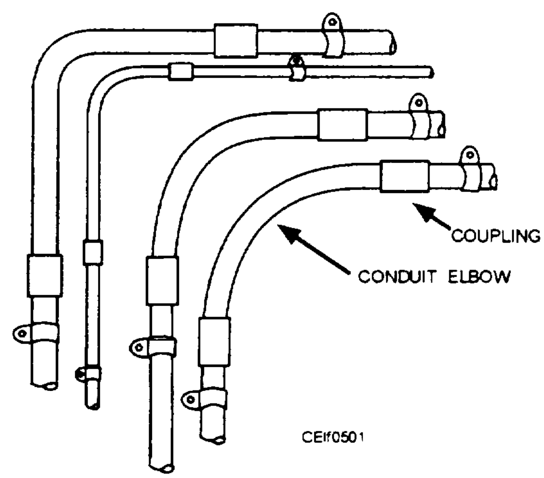


**Figure 5-1.—Right-angle turns with elbows.**

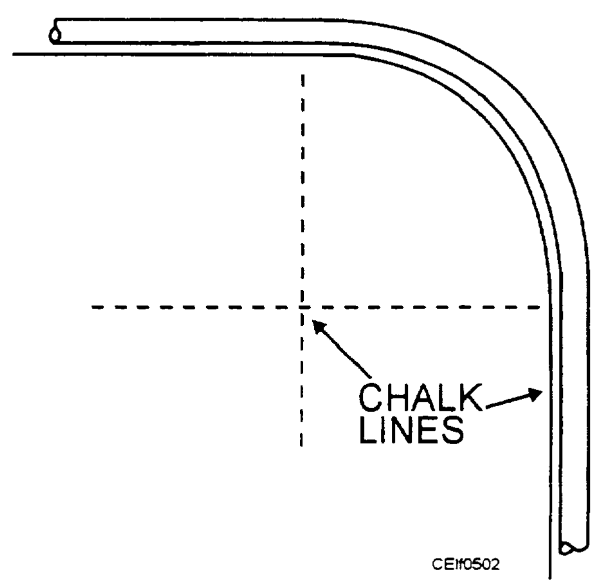


**Figure 5-2.—Forming a conduit to chalk lines.**

be placed parallel at a turn in a multiple run, as shown in figure 5-3. If standard elbows are used, it is impossible to place them parallel at the turns. They will have an appearance similar to the one shown in figure 5-1.

Except as discussed in the NEC®, metal raceways, cable armor, and other metal enclosures for conductors will be joined together into a continuous electric conductor and will be connected to all the boxes, fittings, and cabinets to provide effective electrical continuity. Raceways and cable assemblies will be mechanically secured to boxes, fittings, cabinets, and other enclosures. This action ensures electrical continuity of metal raceways and enclosures.

## WIRING OF BUILDINGS

Normally the power-distribution feeder from the power pole to a building is secured to the building with an insulator bracket. Brackets should be mounted high enough so the power feeders are never suspended lower than 18 feet over driveways and 10 feet over walkways.

Insulator bracket service-entrance conductors run down the side of the building to a point where they enter the building and connect to the service-entrance panel. For commercial and industrial wiring, the greatest percentage of wiring will be installed in a conduit or a raceway. Service-entrance cable should be used for this purpose.

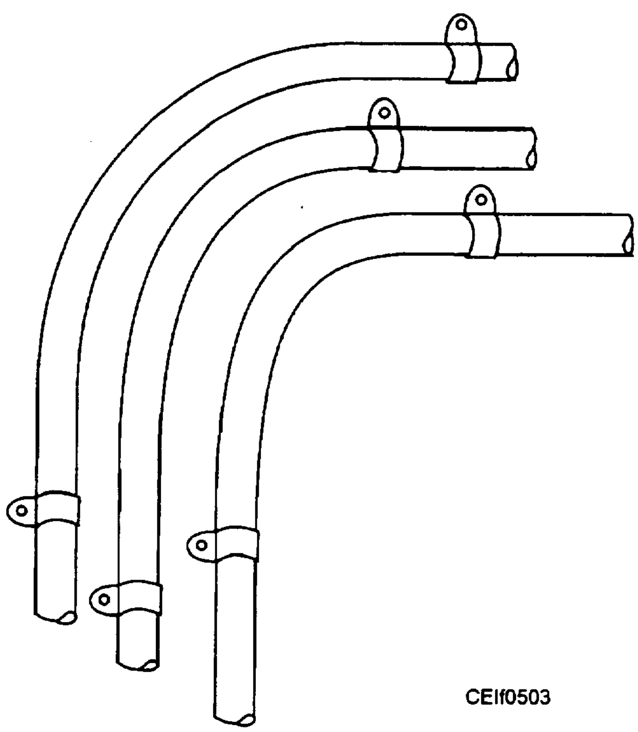


**Figure 5-3.—Right-angle turns with bent conduit.**

Armored cable or nonmetallic-sheathed cable should be used for the interior wiring of the building.

## GROUNDING

At each building, the wiring system must be grounded. This provision is in addition to the ground at the power pole. Grounds must be established at each point of entrance to each building; and, if possible, all these grounds should be tied together on driven grounds. Also, for added safety, the water system should be tied at each building to the driven ground for that building. A well-grounded wiring system adds to the safety of the entire installation.

## WIRING SYSTEM GENERAL PROVISIONS

The following discussion applies to the types of wiring used for voltages up to 600 volts, unless otherwise indicated. Each type of insulated conductor is approved for certain uses and has a maximum operating temperature. If this temperature is exceeded, the insulation is subject to deterioration. In recent years, modified ethylene tetrafluoroethylene (2 and ZW) and perfluoroalkoxy (PFA and PFAH) cables have been allowed for high-temperature operations. Each conductor size has a maximum current-carrying capacity, depending on the type of insulation and conditions of use.

Conductors of more than 600 volts should not occupy the same enclosure as conductors carrying less than 600 volts, but conductors of different light and power systems of less than 600 volts may be grouped together in one enclosure if all are insulated for the maximum voltage encountered. Communication circuits should not occupy the same enclosure with light and power wiring.

Boxes or fittings must be installed at all outlets, at switch or junction points of raceway or cable systems, and at each outlet and switch point of concealed knob-and-tube work.

## PROVISIONS APPLYING TO ALL RACEWAY SYSTEMS

The number of conductors, permitted in each size and type of raceway, is definitely limited to provide ready installation and withdrawal. For conduit and electrical metallic tubing, refer to the NEC®.

Raceways, except surface-metal molding, must be installed as complete empty systems, the conductors being drawn in later. Conductors must be continuous from outlet to outlet without splice. except in auxiliary gutters and wireways.

Conductors of No. 8 AWG and larger must be stranded. Raceways must be continuous from outlet to outlet and from fitting to fitting and will be securely fastened in place.

All conductors of a circuit operating on alternating current, if in a metallic raceway', should be run in one enclosure to avoid inductive overheating. If, owing to capacity, not all conductors can be installed in one enclosure, each raceway used should contain a complete circuit (one conductor from each phase).

Rigid-metal conduit, intermediate metal conduit, and electrical metallic tubing are the systems generally used where wires are to be installed in raceways. Both conduit and tubing may be buried in concrete fills or may be installed exposed. Wiring installed in conduit is approved for all classes of buildings and for voltages both above and below 600 volts. Certain restrictions are placed on the use of tubing; refer to the NEC®.

## LIGHTING AND POWER SYSTEMS

Lighting and power systems start at the panelboards. Refer to the NEC® during the installation of the lighting and power circuits for further guidance. The wiring layout in each of these illustrations determines how the component parts in the circuit will be connected to one another and where the wires will be routed. Careful planning in the wiring layout can result in substantial savings by eliminating long runs of excess wire. It should be pointed out that the wire runs that are shown in the actual construction illustration may not be the most economical use of wire. These wire runs are laid out in a very smooth and definite pattern to make the drawing easier to follow. In many cases, wire runs shown at right angles should be run diagonally to conserve wire. When cable runs are routed on the jobsite, shortening the runs will result in lower installation costs.

## SERVICES AND FEEDERS

No limit is placed on the electrical capacity of service conductors and service protection used in bringing the electric supply into a building, since only one supply should be introduced whenever possible. Near the point of entrance of the supply, the heavy-service conductors are tapped by feeders that conduct the electricity to panelboards at various load centers in the building where the final branch circuits which supply individual lighting, heating, and power outlets originate. No limits are placed on the electrical capacity of feeders; but, for practical purposes, they are limited in size by the difficulty of handling large conductors and raceways in restricted building spaces, by voltage drop, and by economic considerations.

Each lighting fixture, motor, heating device. or other item of equipment must be supplied by either a branch circuit for grouped loads, by an individual branch circuit, or by a motor branch circuit.

## LIGHTING AND APPLIANCE BRANCH-CIRCUIT PANELBOARDS

In solving all installation problems with panelboards, the first consideration is to determine whether the panelboard will be considered a lighting and appliance branch-circuit type. The NEC® rules are much stricter for lighting and appliance branch-circuit panelboards than for other types.

The Code defines a lighting and appliance branch-circuit panelboard as one having more than 10 percent of its overcurrent devices rated 30 amperes or less for which neutral connections are provided. For example, if any panelboard with less than 10 overcurrent devices contains one overcurrent device rated at 30 amperes for which neutral connections are provided, it would be considered a lighting and appliance branch-circuit panelboard (1 ÷ 9 = 11%).

In another example, panelboards that supply loads without any neutral connections are not considered lighting and appliance branch-circuit types whether or not the overcurrent devices are 30 amperes or less.

When it is determined that a panelboard is a lighting and appliance branch-circuit type, the following NEC® rules apply:

1. Individual protection, consisting of not more than two main circuit breakers or sets of fuses having a combined rating not greater than that of the panelboard, is required on the supply side. This main protection may be contained within the panelboard or in a separate enclosure ahead of it. Two exceptions to the Code rule are as follows:

a. Individual protection is not required when the panelboard feeder has overcurrent protection not greater than that of the panelboard. For example, two 400-ampere panelboards can be connected to the same feeder if the feeder overcurrent device is rated or set at 400 amperes or less.

b. Individual protection is not required where such existing panelboards are used as service equipment in supplying an individual residential occupancy. For example, take a split-bus panelboard in which the line section contains three to six circuit breakers or fuses, none of which are rated 20 amperes or less. In such an arrangement, one of the main overcurrent devices supplies the second part of the panel that contains l5- or 20-ampere branch-circuit devices. The other main overcurrent devices (over 20 amperes) supply feeders or major appliances, such as cooking equipment, clothes dryers, water heaters, or air-conditioning equipment (fig. 5-4). Thisarrangement is permitted only for existing panelboards in existing individual residential occupancies.

2. A lighting and appliance branch-circuit panelboard is limited to not over 42 overcurrent devices (excluding the main overcurrent devices) in any one cabinet or cutout box (fig. 5-5). When such devices are numbered, a single-pole circuit breaker is counted as one overcurrent device; a two-pole circuit breaker, as two overcurrent devices; and a three-pole circuit breaker, as three overcurrent devices.

In addition, the panelboards will be provided with physical means to prevent the installation of more overcurrent devices than the panelboard was designed, rated, and approved to handle. Figure 5-6 shows a suitable arrangement for overcurrent devices.

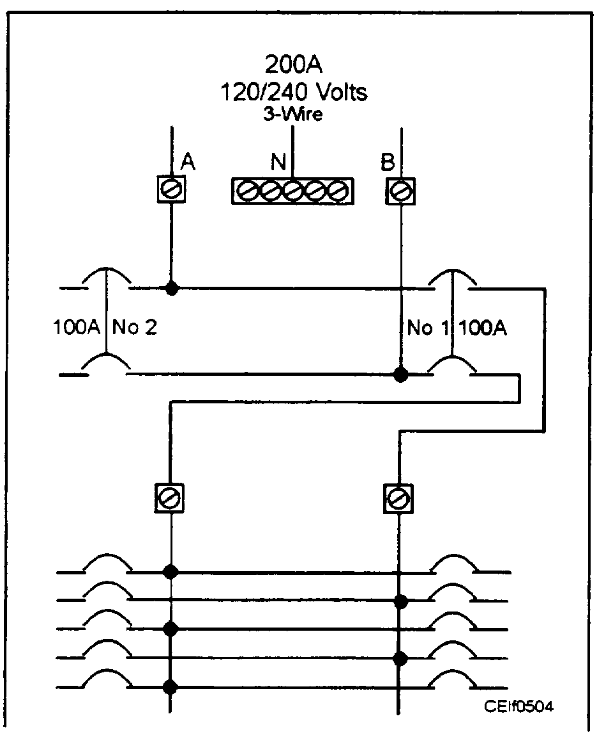


**Figure 5-4.—Typical arrangement of a split-bus lighting panelboard.**

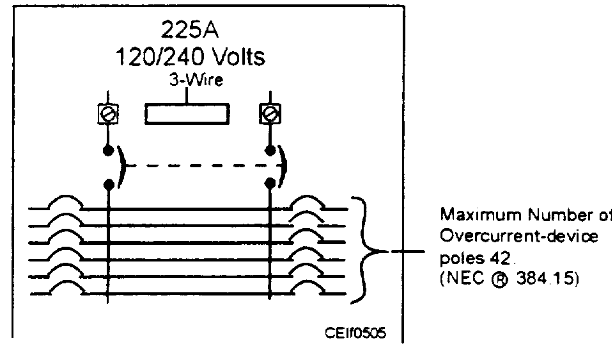


**Figure 5-5.—Typical arrangement that shows NEC® rules for lighting panelboards.**

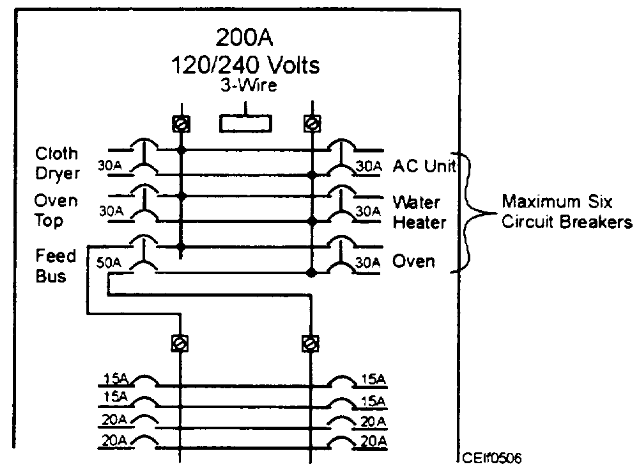


**Figure 5-6.—Suitable arrangement for an existing 200-ampere lighting panelboard used as service equipment for individual residential occupancy.**

A typical lighting panelboard is a circuit-breaker type with a main 200-ampere circuit breaker and thirty-two 20-ampere single-pole breakers. This type of panel is used for a four-wire, three-phase, grounded neutral system. The main breaker is three-pole.

Other NEC® provisions that apply to all types of panelboards are as follows:

1. Panelboards, equipped with snap switches rated 30 amperes or less, will have overcurrent protection not in excess of 200 amperes. Circuit breakers are not considered snap switches.

2. Panelboards that have switches on the load side of any type of fuse will not be installed except for use as service equipment. Panelboard equipment with the snap switch is on the line side of the plug fuses and satisfies the Code.

3. The total load on any overcurrent device, located in a panelboard, will not exceed 80 percent of its rating. If in normal operation, the load will be continuous (3 hours or more) unless the assembly including the overcurrent device is approved for continuous duty at 100 percent of its rating.

Power-distribution panels are similar to the feeder-distribution type. They have bus bars normally rated up to 1,200 amperes at 600 volts or less and contain control and overcurrent devices sized to match connected motor or other power circuit loads. Generally, the devices are three-phase.

Special panelboards. containing relays and contactors, can be obtained and installed when remote control of specific equipment is specified. A thorough knowledge of all the available types of panelboards aids in the selection and installation of the proper unit.

Service-equipment panelboards, for loads up to 800 amperes, containing six or fewer main fused switches, fused pullouts, or circuit breakers are available. These panels constitute service equipment and frequently contain split buses that supply branch circuit or feeder overcurrent devices installed in the same enclosure (figs. 5-4 and 5-6).

Feeder distribution panels generally contain circuit overcurrent devices rated at more than 30 amperes to protect subfeeders that extend to smaller branch-circuit panelboards.

## BRANCH CIRCUITS FOR GROUPED LOADS

The uses and limitations of the common types of branch circuits are outlined in the Summary of Branch-Circuit Requirements (NEC® table 210-24). Lighting branch circuits may carry loads as high as 50 amperes, although florescent lighting is limited to use on circuits of 15-ampere or 20-ampere rating. Such circuits are extensively used in commercial and industrial occupancies. Branch circuits, supplying convenience outlets for general use in other than manufacturing areas, are usually limited to a maximum of 20 amperes. The type of outlet required for heavier capacity circuits usually will not accommodate the connection plug found on portable cords, lamps, motor-driven office machinery, and so forth.

## INDIVIDUAL BRANCH CIRCUITS

Any individual piece of equipment (except motors) also may be connected to a branch circuit meeting the following requirements: Conductors must be large enough for the individual load supplied. Overcurrent protection must not exceed the capacity of the conductors or 150 percent of the rating of the individual load if the single-load device is a nonmotor-operated appliance rated at 10 amperes or more. Only a single outlet or piece of equipment may be supplied.

## MOTOR BRANCH CIRCUITS

Because of the peculiar conditions obtained during the starting period of a motor and because it may be subjected to severe overloads at frequent intervals, motors, except for very small sizes, are connected to branch circuits of a somewhat different design from that previously discussed.

## CONDUCTORS

The Code covers general requirements for conductors and their type designations, insulations? markings, mechanical strengths, ampacity ratings, and uses. These requirements do not apply to conductors that form an integral part of the equipment, such as motors, motor controllers, and similar equipment, or to conductors specifically provided for elsewhere in the Code.

Conductors must be insulated except where covered or bare conductors are specifically permitted by the NEC®. The Code covers the insulation of neutral conductors of a solidly grounded high-voltage system. When stranded conductors are installed, the Code states that stranded conductors installed in raceways must be a size No. 8 or larger with the following exceptions:

Exception No. 1: When used as bus bars or in mineral-insulated, metal-sheathed cable

Exception No. 2: When bonding conductors are required

### Conductors in Parallel

Aluminum, copper-clad aluminum, or copper conductors of size 1/0 and larger, in each phase of the current; neutral; and grounded circuit conductors may be connected in parallel (electrically joined at both ends to form a single conductor).

Exception No. 1: Conductors in sizes smaller than No. l/O AWG will be permitted to run in parallel to supply control power to indicating instruments, contactors, relays, solenoids, and similar control devices provided:

1. They are contained within the same raceway or cable

2. The ampacity of each individual conductor is sufficient to carry the entire load current shared by the parallel conductors

3. The overcurrent protection is such that the ampacity of each individual conductor will not be exceeded if one or more of the parallel conductors become inadvertently disconnected

## Equipment Grounding Conductors

Bare, covered, or insulated grounding conductors will be permitted. Individually covered or insulated grounding conductors will have a continuous outer finish that is either green or green with one or more yellow stripes.

Exception No. 1: An insulated or covered conductor larger than No. 6 will be permited, at the time of installation, to be permanently identified as a grounding conductor at each end and at every point where the conductor is accessible. Identification will be accomplished by one of the following means:

1. Stripping the insulation or covering from the entire exposed length
2. Coloring the exposed insulation or covering green
3. Marking the exposed insulation or covering with green colored tape or green colored adhesive labels

Exception No. 2: Where the conditions of maintenance and supervision assure that only qualified persons will service the installation, an insulated conductor in a multiconductor cable will be permitted, at the time of installation, to be permanently identified as a grounding conductor at each end and at every point where the conductor is accessible by one of the following means:

1. Stripping the insulation from the entire exposed length
2. Coloring the exposed insulation green
3. Marking the exposed insulation with green tape or green colored adhesive labels

The following paragraphs discuss conductors in vertical conduits. You may not work very much with multistory buildings but the knowledge is very important. Conductors in vertical conduits must be supported within the conduit system, as shown in table 5-2.

The following methods of supporting cables will satisfy NEC® requirements:

1. Approved clamping devices are constructed of or use insulated wedges inserted in the ends of the

**Table 5-2.—Spacing of Vertical Conductors Support**

| CONDUCTOR SIZE | CONDUCTORS (IN FEET) | |
|---|---|---|
| | Aluminum or Copper-Clad Aluminum | Copper |
| | Not greater than | Not greater than |
| No. 18 through No. 8 | 100 | 100 |
| No. 6 through No. 0 | 200 | 100 |
| No. 00 through No. 0000 | 180 | 80 |
| 211,601 through 350,000 cmil | 135 | 60 |
| 350,001 through 500,000 cmil | 120 | 50 |
| 500,001 through 750,00 cmil | 95 | 40 |
| Above 750,000 cmil | 85 | 35 |

conduits (fig. 5-7). With cables having varnished-cambric insulation, it also may be necessary to clamp the conductor.

2. Junction boxes may be inserted in the conduit system at required intervals. Insulating supports of an approved type must be installed in the junction boxes and secured in a satisfactory manner to withstand the weight of the attached conductors. The boxes must be provided with proper covers.

3. The cables may be supported in junction boxes by deflecting them (fig. 5-8) not less than 90 degrees and carrying them horizontally to a distance not less than twice the diameter of the cable. The cables may be carried on two or more insulating supports and additionally secured by tie wires. When this method is used, the cables will be supported at intervals not greater than 20 percent of those mentioned in the preceding table.

## TESTING ELECTRICAL CIRCUITS

In this section, you will find out how easy it is to assist and train your crew in troubleshooting. Many different types of electrical multimeters are available to assist you. Electrical circuits can be tested safely and inexpensively with a neon tester (fig. 5-9). Most electrical problems can be solved just by determining the presence or absence of voltage.

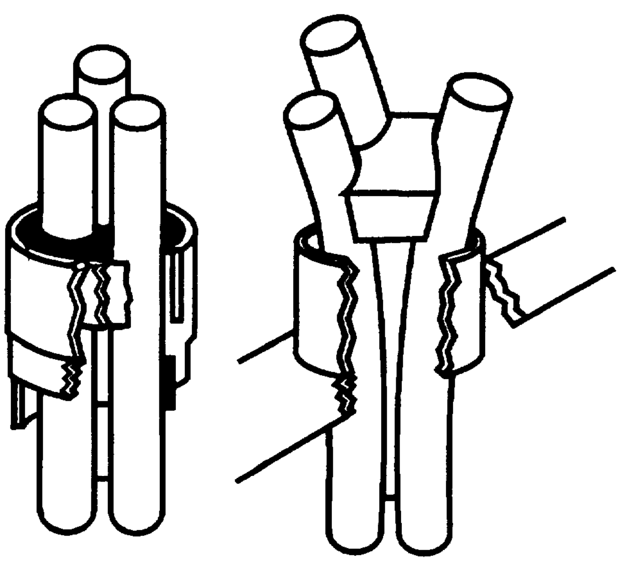


**Figure 5-7.—Gable support screwed on the end of a conduit and the one piece plug type.**

## CHECKING FOR A DEFECTIVE RECEPTACLE

One of the most common tests made with a neon tester is determining whether a receptacle is providing power. Figure 5-10 shows the first step in testing a receptacle. Each lead of the tester is firmly pressed into the receptacle slots to form a good electrical contact.

If voltage is present. the neon tester will glow softly for a 110-volt circuit and more brightly for a 220-volt circuit. If the tester does not light, the receptacle cover should be removed so that a second voltage check can be made at the terminals of the receptacle (fig. 5-11). If voltage is present at the terminals but not at the receptacle, the receptacle is defective and should be replaced. If voltage is not present at either the receptacle or its terminals, the problem lies in the overload protection or in the electrical circuit leading to the troubled receptacle.

When the problem is in the electrical circuit leading to the receptacle, check each splice or each terminal point along the entire circuit for a break or a loose connection.

## CHECKING FOR A DEFECTIVE SWITCH

Determining whether a switch is defective requires only a simple two-step procedure. You must determine whether voltage is reaching the switch and whether voltage is passing through the switch.

Figure 5-12 shows how you can position the neon tester to determine if voltage is reaching the switch. Figure 5-13 shows how you reposition the tester to determine if voltage is going through.

With a grounded system, you need only touch the metal box and the terminals (figs. 5-12 and 5-13), or you may find it necessary to remove the wire nut from the neutral wire and use the neutral as the other test point. If voltage is not present at either switch terminal, the problem lies in the overload protection or in the electrical circuit leading to the troubled switch.

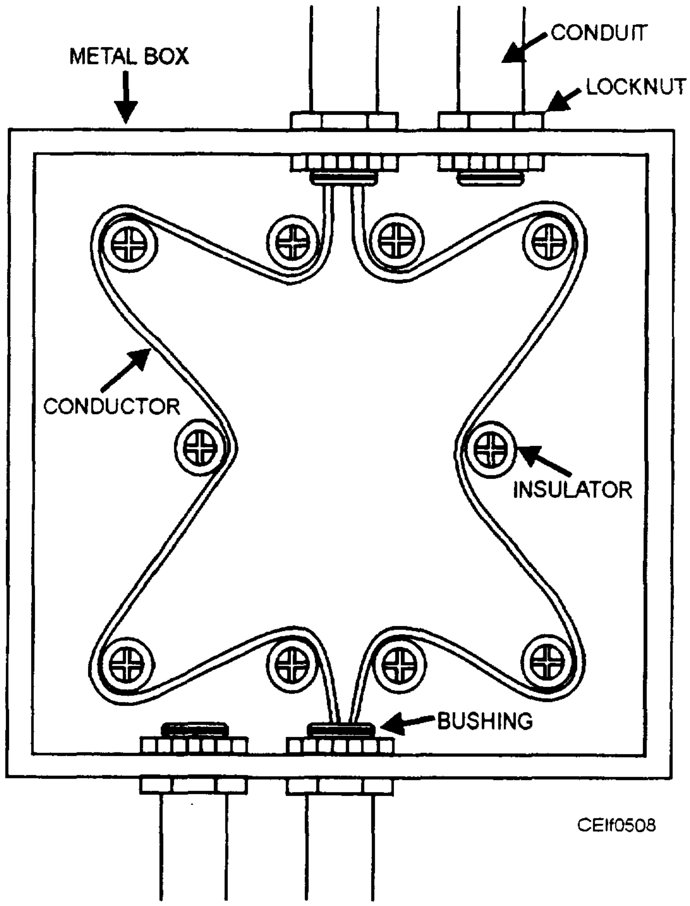


**Figure 5-8.—Supporting conductors in a vertical conductor run.**

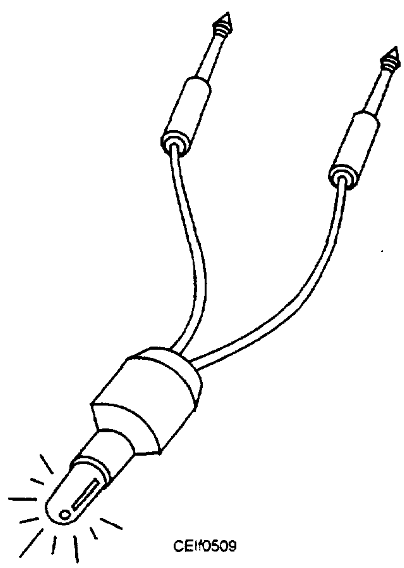


**Figure 5-9.—Neon testers for 110/220-volt circuits.**

When the problem is in the electrical circuit leading to the receptacle, each splice or terminal point should be checked along the entire circuit for a break or loose connection. Before this test procedure is started, be sure the power to the suspected switch has been turned OFF.

**WARNING**

Failure to secure power could result in a fatal electrical shock. More people are killed by normal household current than high voltage. When energized circuits are being worked on, the worker should be trained according to 29 CFR 1910.333 and use the protective equipment specified in 29 CFR 1910.335.

Remove the faceplate from the switch and unscrew the switch from the junction box. Pull the switch away from the metal box and position it so that no bare wires can touch the box. When the switch is in a SAFE position, power may be restored and the test procedure started.

## CHECKING FOR THE HOT WIRE

In remodeling you may find it necessary to check which wires provide power to the circuit and which wires merely continue on to feed other circuits. The neon tester can simplify this procedure by individually

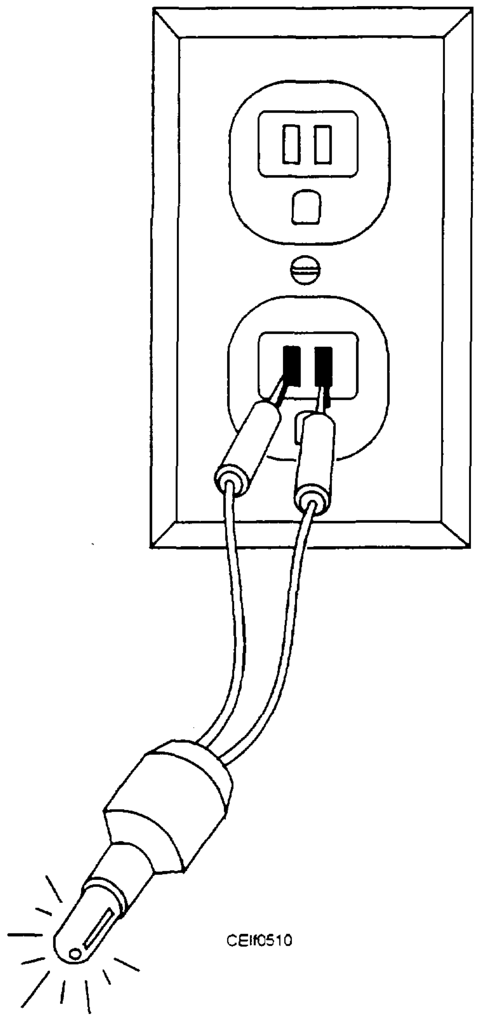


Figure 5-10.—First step in testing an outlet with a neon tester.

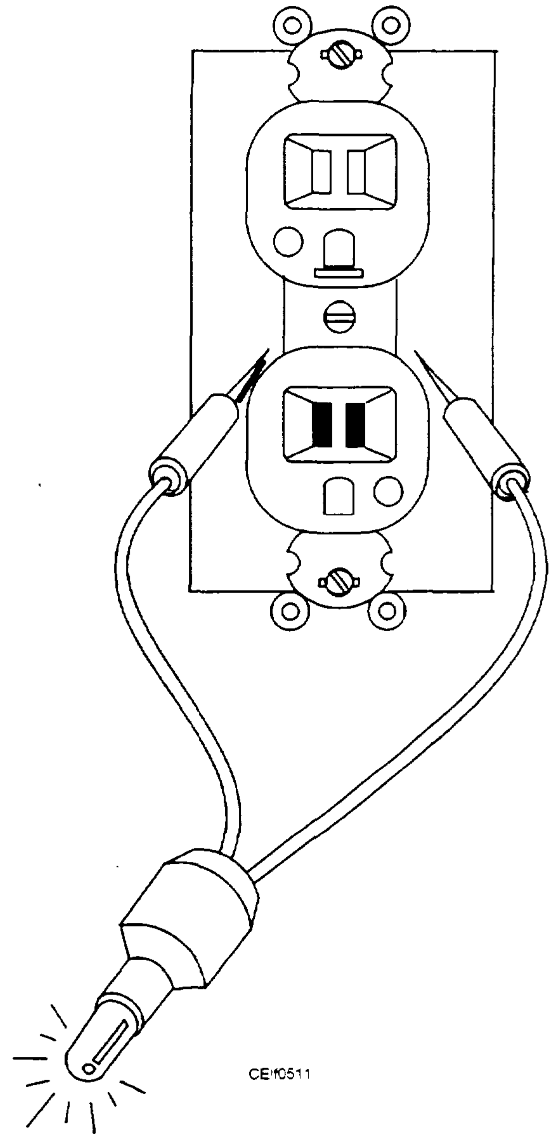


Figure 5-11.—Using the neon tester to check for a defective receptacle.

identifying each pair of wires. The pair that is hot will cause the neon tester to glow.

The grounded system is easiest to check because only the potential hot wires need to be disconnected, separated, and tested. Figure 5-14 shows how the wires are separated and tested. The wire that causes the neon tester to respond is the hot lead.

An ungrounded system can be checked just like a grounded system? except the solderless connector must be removed from the neutral wire and the neutral wire must be used as a reference, as shown in figure 5-15. Figure 5-16 shows how to determine if voltage is reaching a light fixture. With the switch in the ON position, the neon tester should light.

## TESTING THE GROUND TERMINAL

A simple test procedure, as shown in figure 5-17, may be used to check each receptacle for ground.

One lead of the neon tester should be held stationary on the ground terminal while the opposite lead is repositioned on each plug slot. If the receptacle is properly grounded, the neon light will light when placed in only one of the slots. If the light does not glow in either slot, the receptacle is not grounded.

## TESTING CIRCUIT BREAKERS AND FUSES IN CIRCUITS

When you are troubleshooting large electrical systems, it is important to follow the systematic approach: localize, isolate, and locate. It is never a good procedure to make haphazard measurements in a system hoping that luck will lead to the problem. Testing circuit breakers and fuses in the circuit first may eliminate unnecessary troubleshooting. Practice

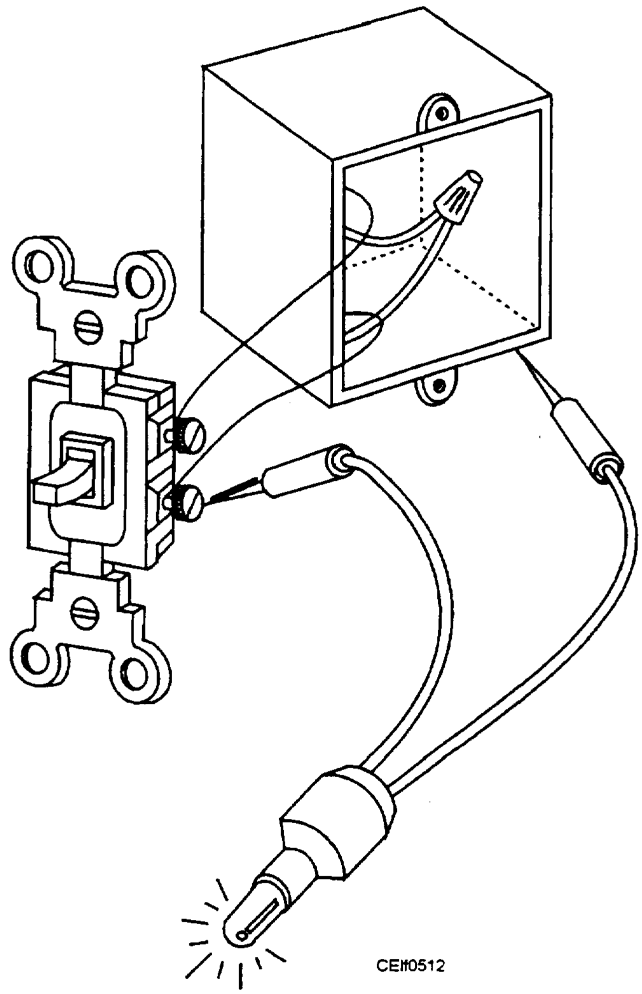


Figure 5-12.—Checking a switch in the OFF position for proper operation.

safe habits. Remember that getting too friendly with electricity can be a shocking experience.

### Circuit Breaker

A circuit breaker operates much the same as a switch-the breaker is either ON or OFF. The neon tester lead is placed on the neutral bar and the other lead is placed on the screw terminal of the circuit breaker (fig. 5-18). If the breaker is good, the neon tester will light when the breaker is in the ON position and will not light when the breaker is in the TRIPPED position.

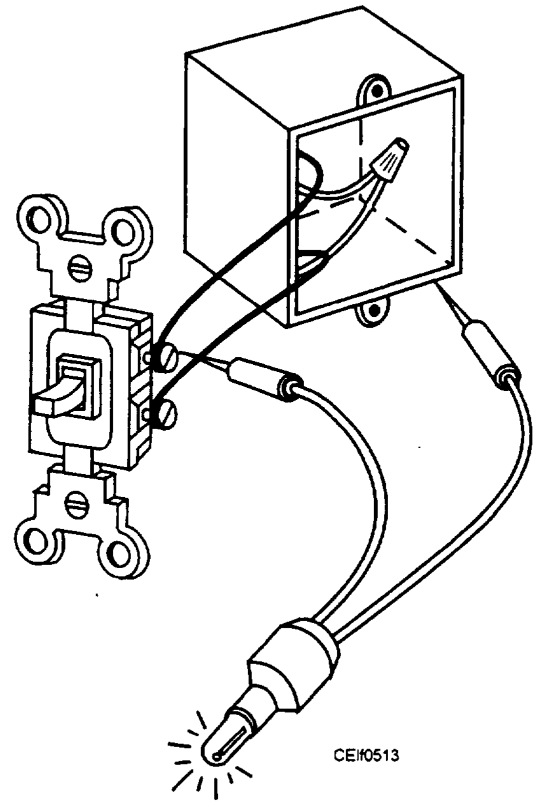


Figure 5-13.—Checking a switch in the ON position for proper operation.

If the neon tester remains lighted in both positions, the breaker is shorted and should be replaced. If the neon tester does not light in either position, the circuit breaker is open and should be replaced. Remember to reset the circuit breaker.

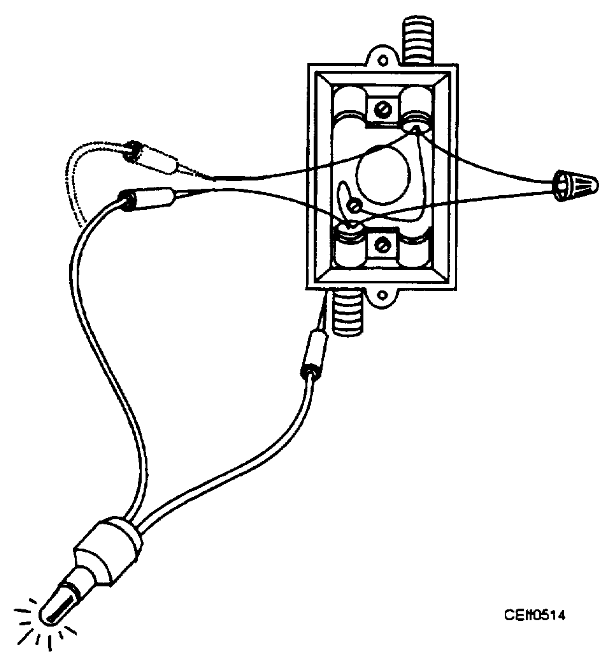


Figure 5-14.—Technique for determining which wire is hot.

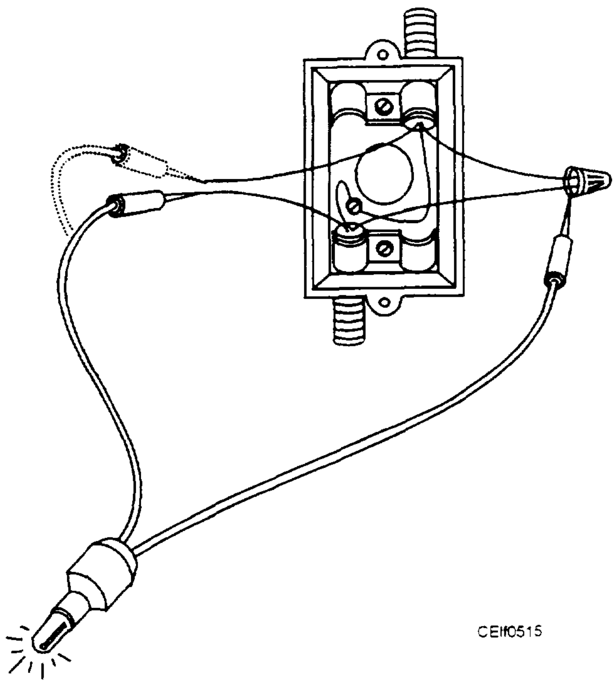


Figure 5-15.—Checking for the hot wire in an underground system with neutral wire exposed.

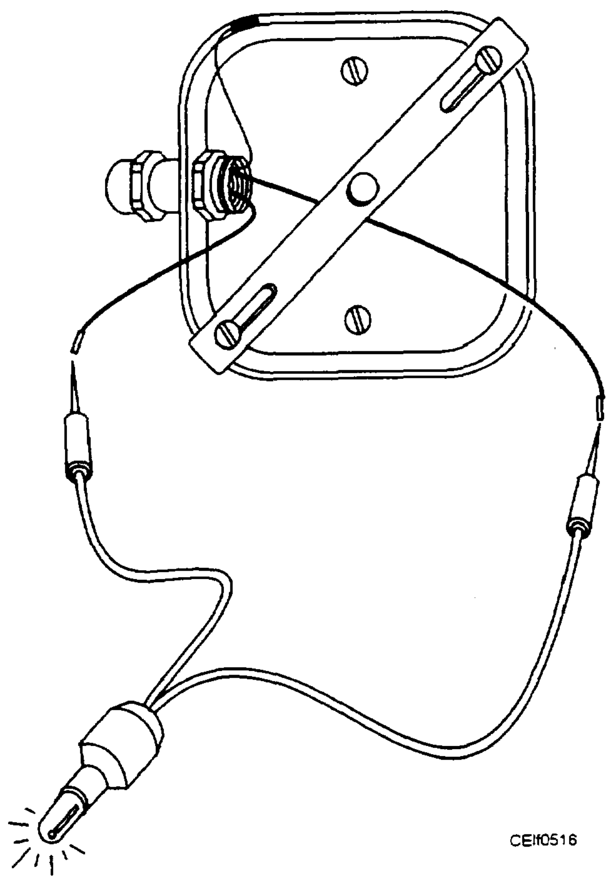


Figure 5-16.—Technique for determining if voltage is reaching a light fixture.

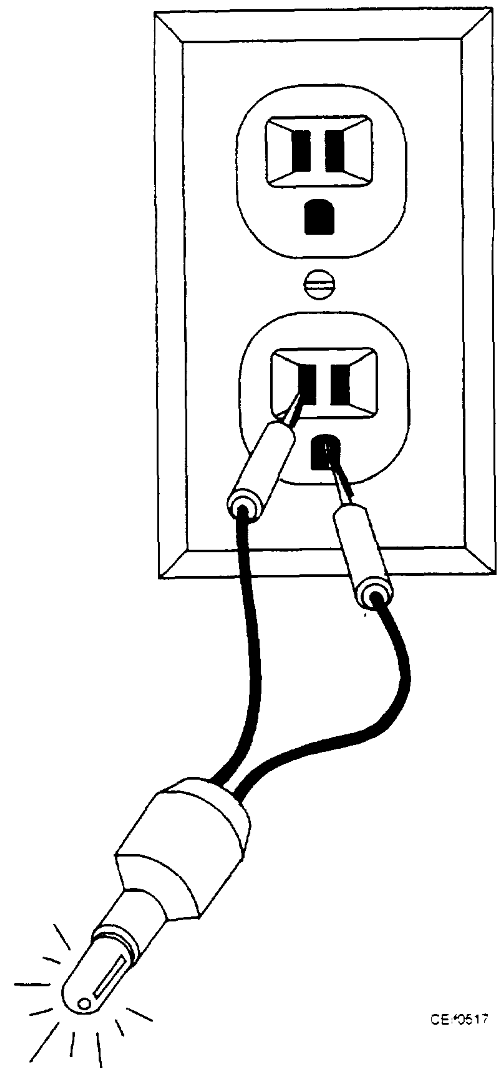


Figure 5-17.—Checking for a properly grounded receptacle.

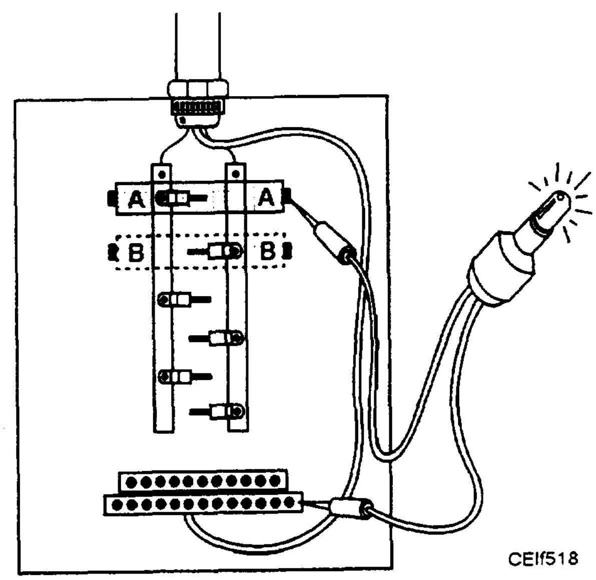


Figure 5-18.—Testing for proper operation of a circuit breaker.

### Fuse

When a fuse is suspected of being defective, it may be checked with a neon tester using the four-part procedure shown in figure 5-19.

1. First determine if the voltage is present at the top of the fuses from the incoming lines. (Light should glow.)

2. Determine if the voltage is passing through the fuse. (If the neon tester fails to light, one or both fuses are defective.)

3. Check the left fuse to see if the voltage is present. If the light glows, the fuse is good; however, if it fails to light, the fuse is defective. Shut off the power and replace the fuse.

4. Check the right fuse to see if the voltage is present. If the light glows, the fuse is good; however, if it fails to light, the fuse is defective. Shut off the power and replace the fuse.

**WARNING**

To prevent electrical shock, do not replace the fuses unless the circuit is de-energized and then only with fuse pullers.

## BENDING CONDUIT

Bending conduit is an art. Like all forms of art, the more often it is done correctly, the more proficient the artist becomes. It is recommended that you attend the SCBT 240.2 course that covers bending and installation of electrical conduits using mechanical benders. Keep in mind that practice will improve your skills and always read and follow the manufacturer's instruction guide. Following the guide will normally assure that you make top quality bends in a safe and efficient manner.

## POWER BENDERS

Power benders are used for bending larger sizes of electrical metallic tubing (EMT), intermediate metallic tubing (IMC), and rigid conduit. Power benders come in many types and sizes. Some of the common ones are the hydraulic one-shot, sweep, and thin-wall benders. As for the mechanical benders, the thin-wall and sweep benders are common. The hydraulic benders use either a hand pump or an electric pump to move a shoe that does the actual bending. Figure 5-20 shows a hydraulic sweep bender that uses a hand pump. By using different sizes of bending dies at different locations on the tie bar, you can use this bender to bend several types and sizes of conduit. The procedures for making the different types of bends with power benders are very similar to those used with manual benders. The main difference is that with the power benders, the take-up for 90-degree bends and the distance between bends for offsets will not be the same. This difference occurs because you are dealing with larger sizes of conduit or the shoes of the bender give a different radius of bend. Because there are so many different types and manufacturers of benders, remember to check the manufacturer's instruction guide before doing any bending.

## BENDING FUNCTIONS AND SAFETY TIPS

In the following paragraphs, we will discuss some general information concerning power benders. This information does not replace the manufacturer's instruction guide, but only acquaints you with some basic functions and safety tips that you (as a crew leader) must be aware of.

When you are bending conduit, the bender must be in a horizontal position. When moving the bender any distance, place the pipe supports and pins in a 4-inch to 5-inch hole position. Then stand up the bender and roll it.

When connecting the high-pressure hose to the female quick-coupler on the end of the ram and the other end to the high-pressure pump female coupler, make sure that the quick-coupler is clean before making the connection. For the correct procedures for removing all the air from the pump and hoses, refer to the manufacturer's manual.

Some mechanical benders have an electrical power pump that is used to apply pressure on the ram. In this case, to operate the hydraulic pump, the motor must be running. Also, the quickest way to stop the advance of the ram is to stop the motor of the power pump.

**WARNING**

Read the pump operating instructions before operating the pump. Always place the control lever in the return position before starting the electric motor pump.

Regardless of what hydraulic bender you use, you must always check the manufacturer's charts and tables for the minimum stub length. When the

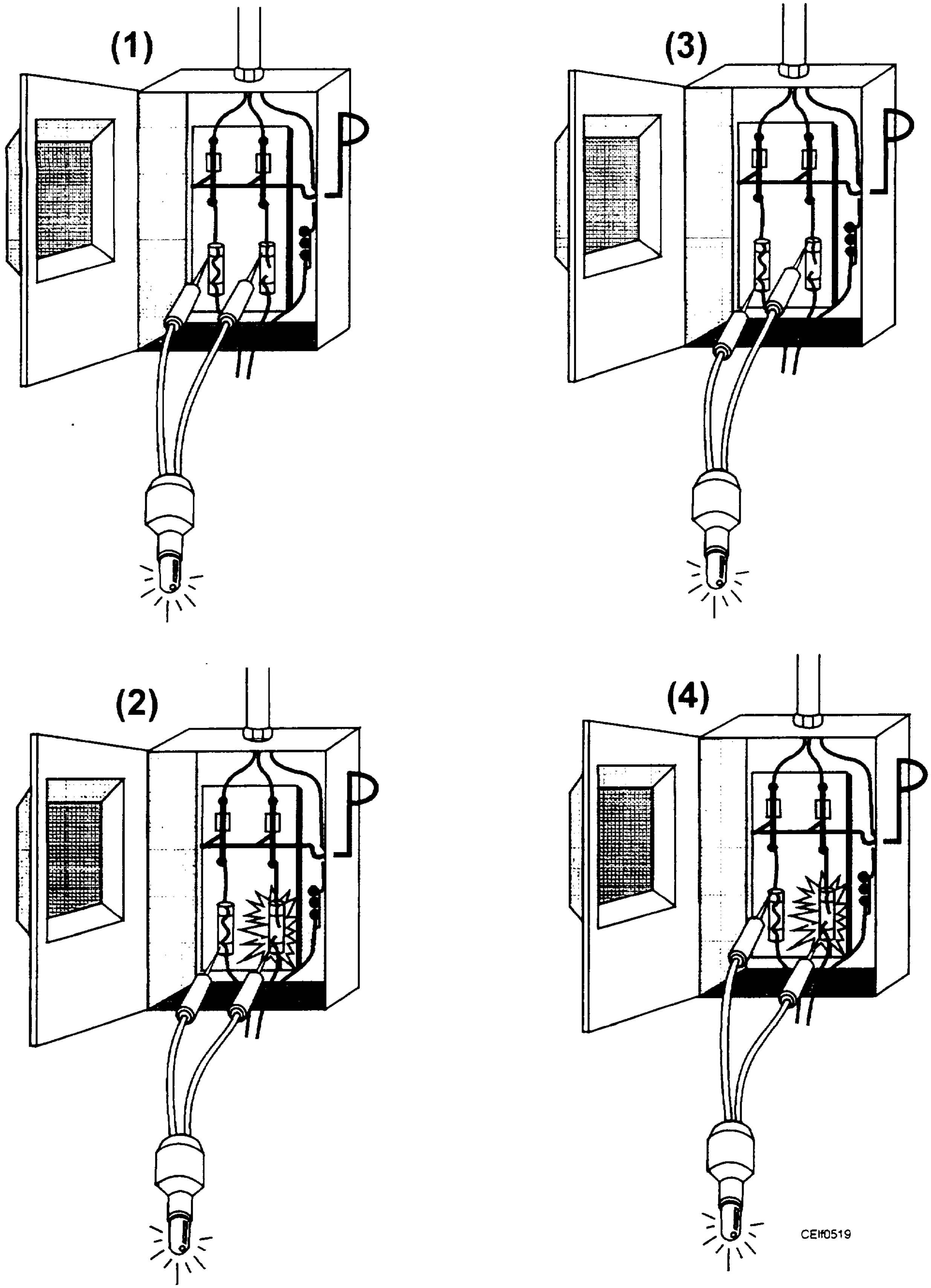


**Figure 5-19.—Procedure used with a neon tester to isolate a defective fuse in a live circuit.**

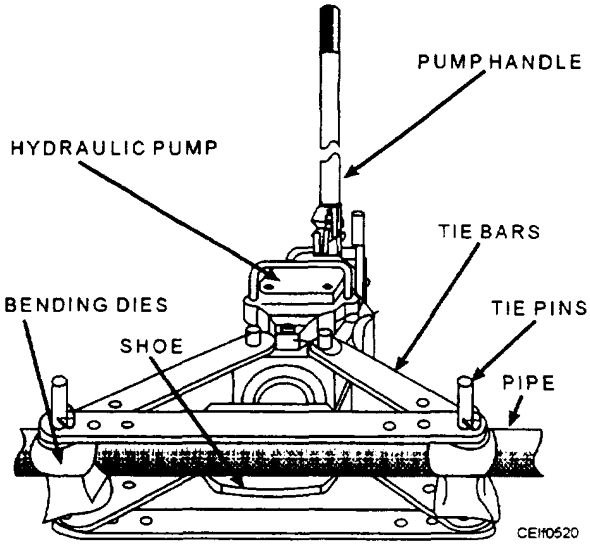


**Figure 5-20.—Hydraulic sweep bender with hand pump.**

manufacturer's tables and charts are not available, the conduit stub length must be equal to or greater than the minimum shown in table 5-3.

When bending conduit up to 90 degrees with a bender that has a ram travel scale, you should make your bend according to the ram travel scale reading.

An offset bend requires two bends of the same degree. To determine the distance between the two bends, you must first decide on the distance in inches of the offset and the degree of bend your conduit routing requires. Remember that the maximum conduit size and offset in inches may restrict your bend. Mark and bend your conduit according to the benders manufacturers' instructions, tables, and charts.

**Table 5-3.—Conduit Size/Deductions/Mininum Stub Lengths**

| CONDUIT SIZE | DEDUCT | MINIMUM STUB LENGTH |
|---|---|---|
| 1/2 | 1 15/16 | 10 |
| 3/4 | 1 1/2 | 10 |
| 1 | 1 7/8 | 13 |
| 1 1/4 | 2 3/8 | 15 13/16 |
| 1 1/2 | 2 3/4 | 18 3/4 |
| 2 | 3 1/4 | 21 9/16 |
| 2 1/2 | 4 1/8 | 25 |
| 3 | 4 15/16 | 28 1/8 |
| 3 1/2 | 5 3/4 | 31 |
| 4 | 6 1/2 | 33 7/8 |

If you have access to a conduit pipe holder (normally for 1 1/4-inch to 4-inch conduit), it will simplify your work by keeping the pipe in perfect alignment at all times, achieving an outstanding bend. When offset bends are being made, the pipe holder permits making the first bend and then reversing the pipe end and making the second bend. The second bend will then be 180 degrees opposite the first bend.

**CAUTION**

Before using any pipe bender, make sure the quick-lock pins are through the holes in the bottom frame and the eccentric pin is turned clockwise past the ball lock. Also, make sure the correct sides of the pipe support pins are in the proper holes. Failure to ensure correct pin placement could result in damage to the conduit and/or the bender.

Occasionally conduit will require more bending. In this case, place the conduit in the bender and continue bending to the desired degree. This step is not necessary when using the Bending Degree Indicator (used for exact bends and reduces the necessity to correct bending caused by springback) or when using the Bending Degree Protractor because the bend will be accurate.

When you are bending long lengths of conduit, conduit pipe holders are very useful. Check the manufacturer's instruction guide for tables and charts that give vital information about conduit bending kit attachments.

When you have to make a large sweep 90-degree radius bend, you will need to get the operating manual of the bender you are using and follow the suggested procedures for marking the bend spacing and finding the necessary center location.

One of the benders that you may use in the field is the Greenlee™ 880 M2 Lightweight Hydraulic Bender. This bender is designed to make bends up to 90 degrees on rigid conduit from 1/2 inch to 2 inches inclusive. The 15-ton ram, the bending shoes, and the frame unit allow a complete 90-degree bend to be made with one piston stroke. The units of the bender can be rapidly and easily assembled for operation without any tools. By using the bending instructions and the piston scale, you can make accurate bends. To assure easy portabiliy, the manufacturer has designed the pipe supports for use as rollers; and parts are made of light-but-strong aluminum alloy whenever possible.

In the bending process, if the pipe is bent to the correct scale reading, overbends will not result. However: if you need to correct an overbend, you must follow the manufacturer's instructions that cover the bender that you are using.

As mentioned earlier, bending conduit is an art. The more you practice, the better you will be. Most bending charts show information on how to make bends to 15°. 30°, 45°, 60°, 90°, 180° and offset bends. When degrees of bend other than these are required and it is important that the bend be accurate. the Bending Degree Indicator should be used. The Bending Degree Indicator is extremely accurate and is very easy to use. The indicator also should be used when making segment bends to center radii greater than those of the bending shoe.

## CONDUIT SUPPORTS AND INSTALLATION METHODS

To install conduit overhead and underground properly, you need to review the appropriate articles of the Code. Conduit should run as straight and direct as possible. There should never be more than the equivalent of four right-angle bends between outlets or fittings.

In installing exposed conduit runs where there are several conduits in the run. it is usually better to carry the erection of all of them together. rather than to complete one line before starting the others. If all are carried together. it is easier to keep all the raceways parallel. particularly at turns. and chances are that the job will look better.

Conduit can be supported on surfaces with pipe straps made in one-hole and two-hole types. On wooden surfaces, wood screws secure the straps in position. On masonry surfaces, machine screws that turn into lead expansion anchors can be used. Wooden plugs should never be used because no matter how well seasoned a plug appears to be, it usually will dry out to some extent and loosen in the hole. When laying out multiple-conduit runs, you must keep in mind the spacings between the conduits to permit proper placing of the straps. The screw-hole dimension (see table 5-4) enables you to order screws of the proper diameters to support the straps.

## LOCATION OF CONDUIT SUPPORTS

The Code states that rigid-metal conduit will be firmly secured within 3 feet of each outlet box, junction box, cabinet, or fitting. The Code permits this distance to be increased to 5 feet where structural members do not readily permit fastening within 3 feet. Rigid-metal conduit will be supported at least every 10 feet; except that straight runs of conduit made up of

**Table 5-4.—Spacings Requirements When Laying Out Multiple-Conduit Runs**

| Size of conduit (inches) | Conduit. width of opening (inches) | Conduit, height of opening (inches) | Width of conduit strap (inches) | Distance between centers of screw hole (inches) | Diameter of screw hole (inches) | Size of wood screw required |
|---|---|---|---|---|---|---|
| 1/4 | 9/16 | 17/32 | 5/8 | 1-9/16 | 0.20 | No. 8 × 5/8" |
| 3/8 | 1 1/16 | 21/32 | 5/8 | 1-3/8 | 0.20 | No. 8 × 3/4" |
| 1/2 | 7/8 | 25/32 | 5/8 | l-5/8 | 0.20 | No. 8 × 3/4" |
| 3/4 | 1/18 | 1 | 3/4 | 2-1/8 | 0.22 | No. 10 × 3/4" |
| l | 1-3/8 | 1-11/32 | 3/4 | 2-3/8 | 0.22 | No. 10 × 7/8" |
| 1-1/4 | 1-3/4 | l-5/8 | 1-13/16 | 2-3/4 | 0.22 | No. 10 × 1" |
| 1-1/2 | 2 | 1-7/8 | 1-13/16 | 3 | 0.22 | No. 10 × 1" |
| 2 | 2-1/2 | 2-5/16 | 1 | 3-3/4 | 0.22 | No. 10 × 1- 1/4" |
| 2-1/2 | 2-3/4 | 2-15/16 | 7/8 | 4-3/3 | 0.25 | No. 11 × 1- 1/4" |

approved threaded couplings may be secured as shown in table 5-5, provided such fastening prevents transmission of stress to terminations when conduit is deflected between supports.

**Table 5-5.—Spacing of Rigid-Metal Conduit Supports**

| CONDUIT SIZE (INCHES) | RIGID-METAL SUPPORT (FEET) |
|---|---|
| 1/2 and 3/4 | 10 |
| 1 | 12 |
| 1-1/4 and 1-1/2 | 14 |
| 2 and 2-1/2 | 16 |
| 3 and larger | 20 |

**CONDUIT HANGERS AND SUPPORTS**

A variety of conduit hangers and supports and several applications are shown in figure 5-21. U-channel supports are ideal for supporting several runs of conduits. In laying out these supports, consideration should be given to future conduit runs as well as those to be installed initially. It is a simple matter to provide U-channels or trapeze hangers with additional space for future conduits. This procedure greatly reduces the cost of installing new conduit at a later date. With the U-channel system, as shown in figure 5-21, special clamps are slipped into the channel slot, and the top bolt of the clamp securely fastens the conduit to the U-channel.

The U-channel can be directly fastened to a wall or ceiling, or it can be attached to bolted threaded rod

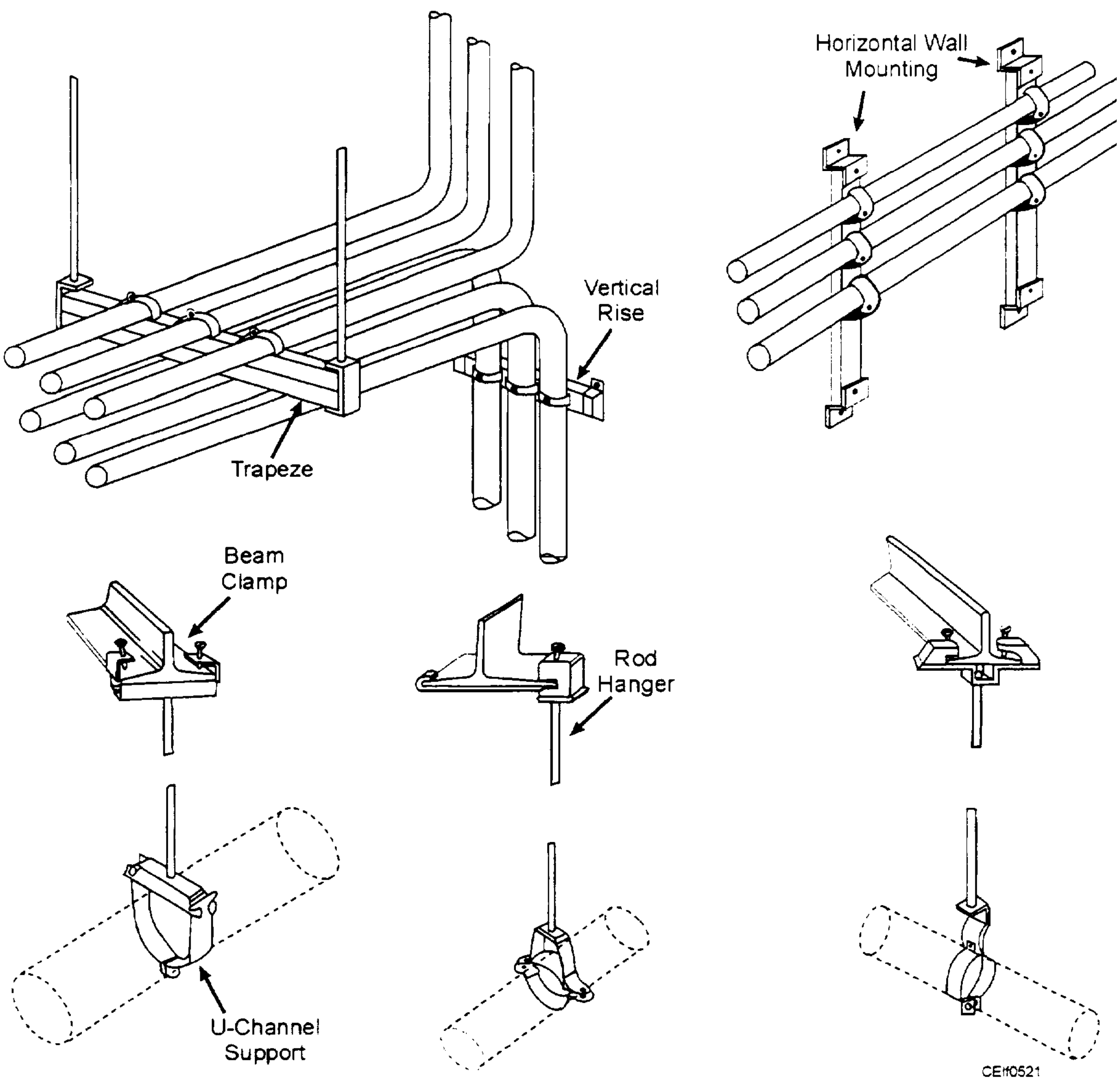


**Figure 5-21.—Common conduit supports.**

hangers suspended from ceilings, roof structures, or similar members.

Another excellent application for the U-channel is in suspended ceilings that contain lift-out ceiling panels. In modem construction, these lift-out panels provide ready access to mechanical and electrical equipment within the suspended-ceiling area. Accordingly, it is important that conduits installed in such an area do not prevent the removal of panels or access to the area. Rod-suspended U-channels provide the solution to conduit wiring in such areas.

Sections of the U-channel and associated fittings are available in aluminum or steel types. Another type of material that can be used for supports is slotted-angle-steel units. Numerous prepunched slots allow installers to bolt on rods, straps, and similar material without drilling holes. Slotted steel has unlimited applications in forming special structures, racks, braces. or similar items.

A cable-pulling kit (80149) has everything needed for any wire or cable-pulling job. Most large Public Works and all battalions have the wire installation kit. The heavy-duty power wire/cable puller plugs into any convenient 115-volt source. It pulls 15 feet of cable per minute and can be used with various attachments for almost any type of pulling job.

After a “fish” line has been blown or run through the conduit, a rope that is provided with the power cable puller can be pulled through the conduit. This rope. used with a cable grip, makes the actual pull. The power cable puller can be used in almost any configuration. Figures 5-22 through 5-27 are examples of the different setups.

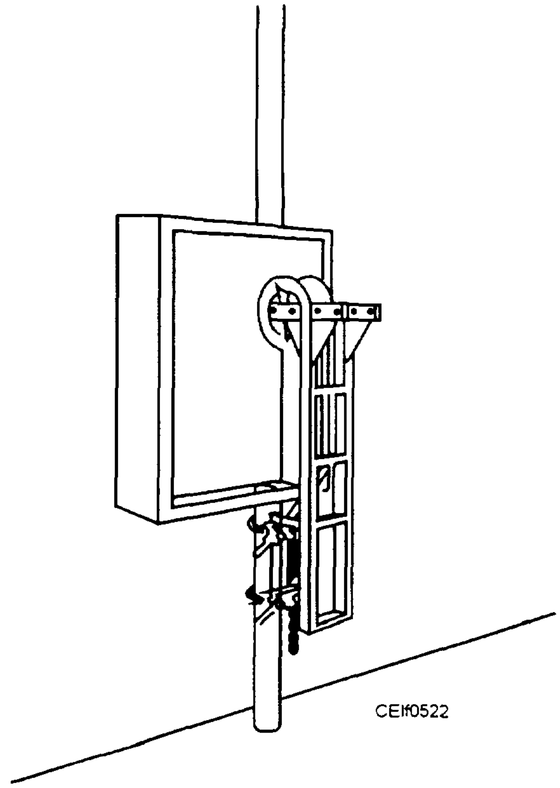


**Figure 5-22.—Pipe adapter to exposed conduit.**

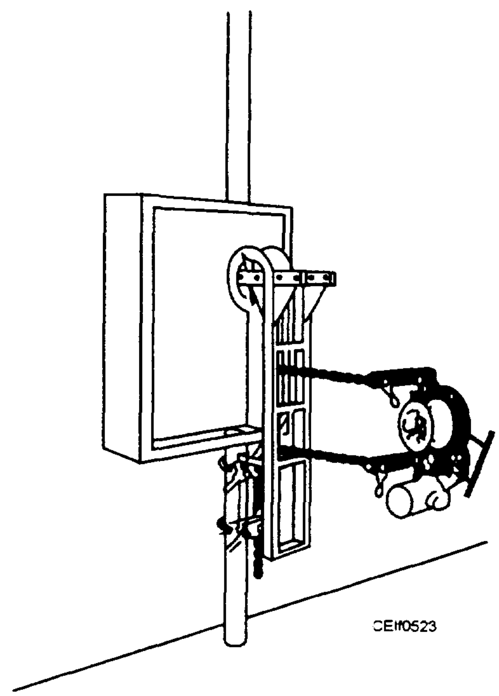


**Figure 5-23.—Power unit to the power adapter.**

## SOLDERING AND SPLICING PROCEDURES

As a CE project supervisor or crew leader, you need to train your crew on the proper solderless connector splices, soldering splices, and taping splices. You will need to spot-check the connections to ensure proper installation.

### SOLDERLESS CONNECTORS

Solderless connectors (wire nuts) have almost completely eliminated soldering and taping for certain types of splices. They are designated to hold several electrical wires firmly together and provide an insulating cover for the wires. They are available in several sizes. The size of the solderless connector is determined by the number and the size of the wires to be joined.

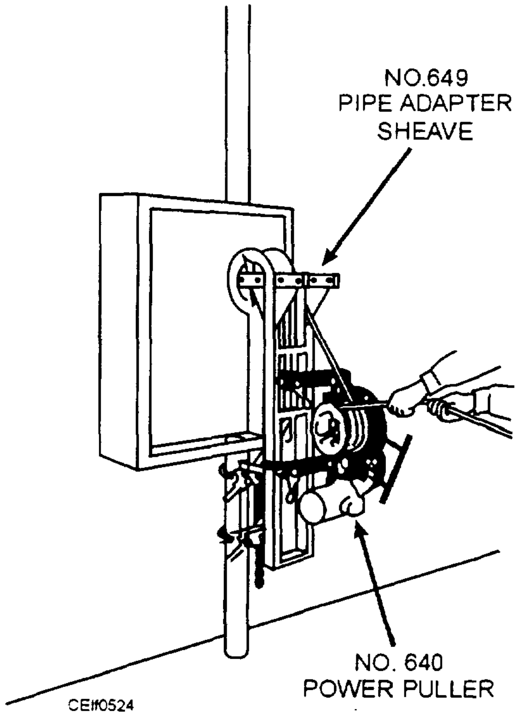


**Figure 5-24.—"Up" pull, using exposed conduit.**

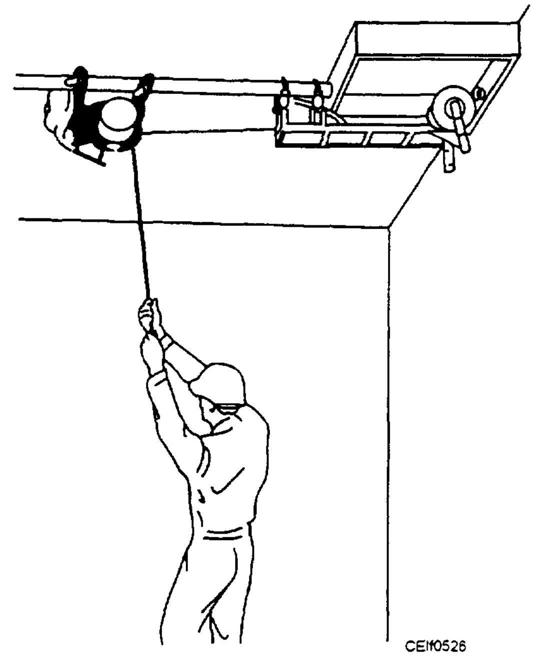


**Figure 5-26.—Pulling in an overhead pull box with the puller mounted independently for extra cable.**

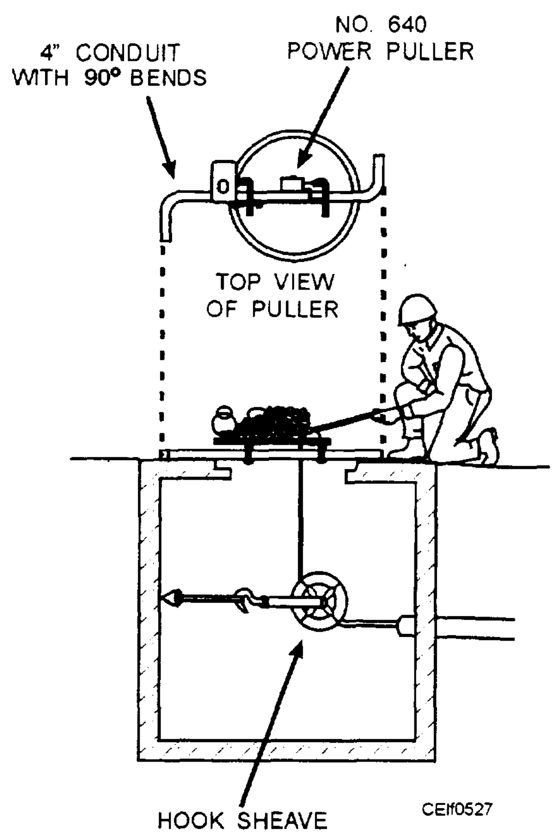


**Figure 5-27.—Setup for ground pull.**

## SPLICES

An electrical splice is the joining of two or more electrical conductors by mechanically twisting them together or by using a special splicing device. Since splices can cause electrical problems, they must be made carefully. Splices must be able to withstand any reasonable mechanical strain that might be placed on the connection. They also must allow electricity to pass through as if the wire had never been broken. Some of the more common splices are explained below.

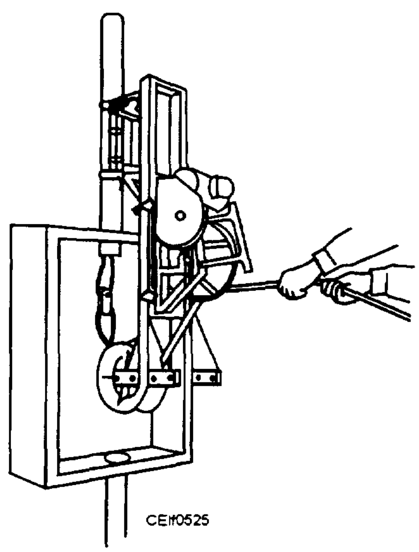


**Figure 5-25.—"Down" pull, using exposed conduit.**

### Pigtail Splice

Because it is simple to make, the pigtail splice is probably the most commonly used electrical splice.

Figure 5-28 shows how to make a pigtail splice. Note the two ways to end the splice. When the splice is taped. the ends must be bent back so the sharp edges will not penetrate the tape (fig. 5-28). When a solderless connector is used instead of tape. the ends are cut off (fig. 5-28). When more than two wires are joined in a pigtail splice, as shown in figure 5-29, they should be twisted together securely before the solderless connector is put on. Twisting the wires together first ensures that all the wires are fastened together properly.

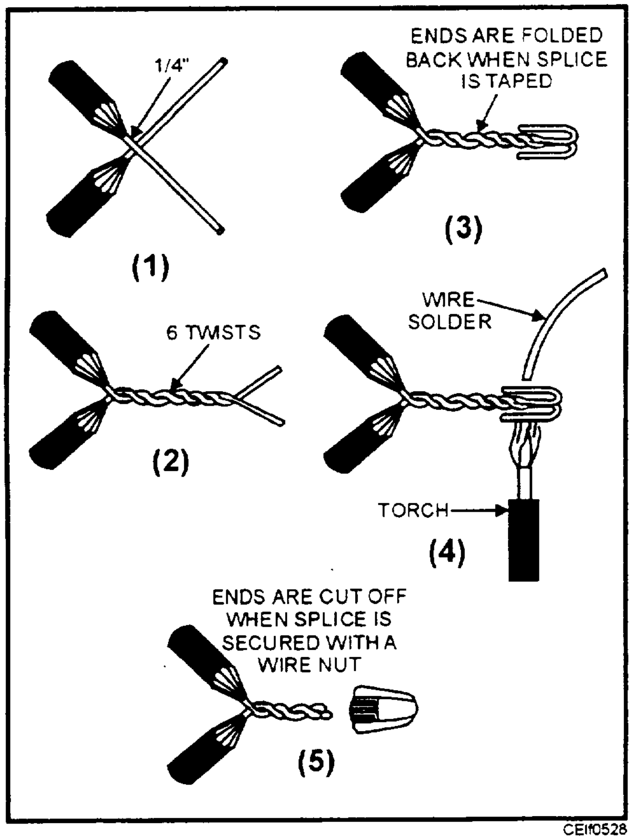


Figure 5-28.—Simple pigtail splice.

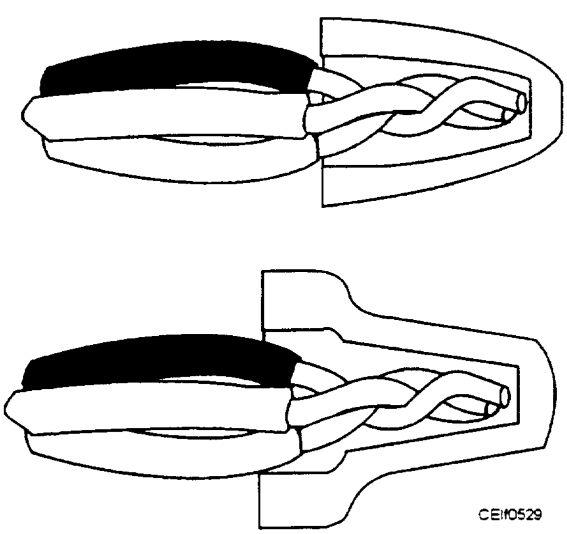


Figure 5-29.—Multiple-wire pigtail splice.

### Western Union Splice

The Western Union splice (fig. 5-30) is used when the connection must be strong enough to support long lengths of heavy, wire. In the past. this splice was used to repair telegraph wires. If the splice is to be taped, care should be taken to eliminate any sharp edges from the wire ends.

### T-tap

The T-tap (fig. 5-31) is a type of splice that allows a connection to be made without cutting the main line. This connection is one of the most difficult to make. A certain amount of practice may be necessary to make this connection look neat. Study figure 5-3 1 to determine the proper technique in making this splice.

### Portable Cord Splices

Cord splices are weak because there is no connector to hold them together; therefore. they should be used for emergency purposes only. If the cord must be saved, use twist lock plugs and receptacles to rejoin the cord. Figure 5-32 shows how solid wires are spliced. The individual splices are staggered to prevent a large bump when the cord is taped. Additional strength may be added to this splice by soldering each individual splice.

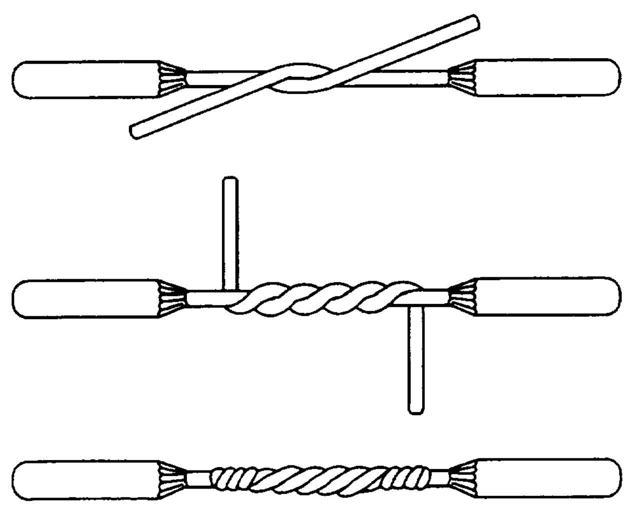


Figure 5-30.—Western Union splice used where substantial strain may be placed on the connection.

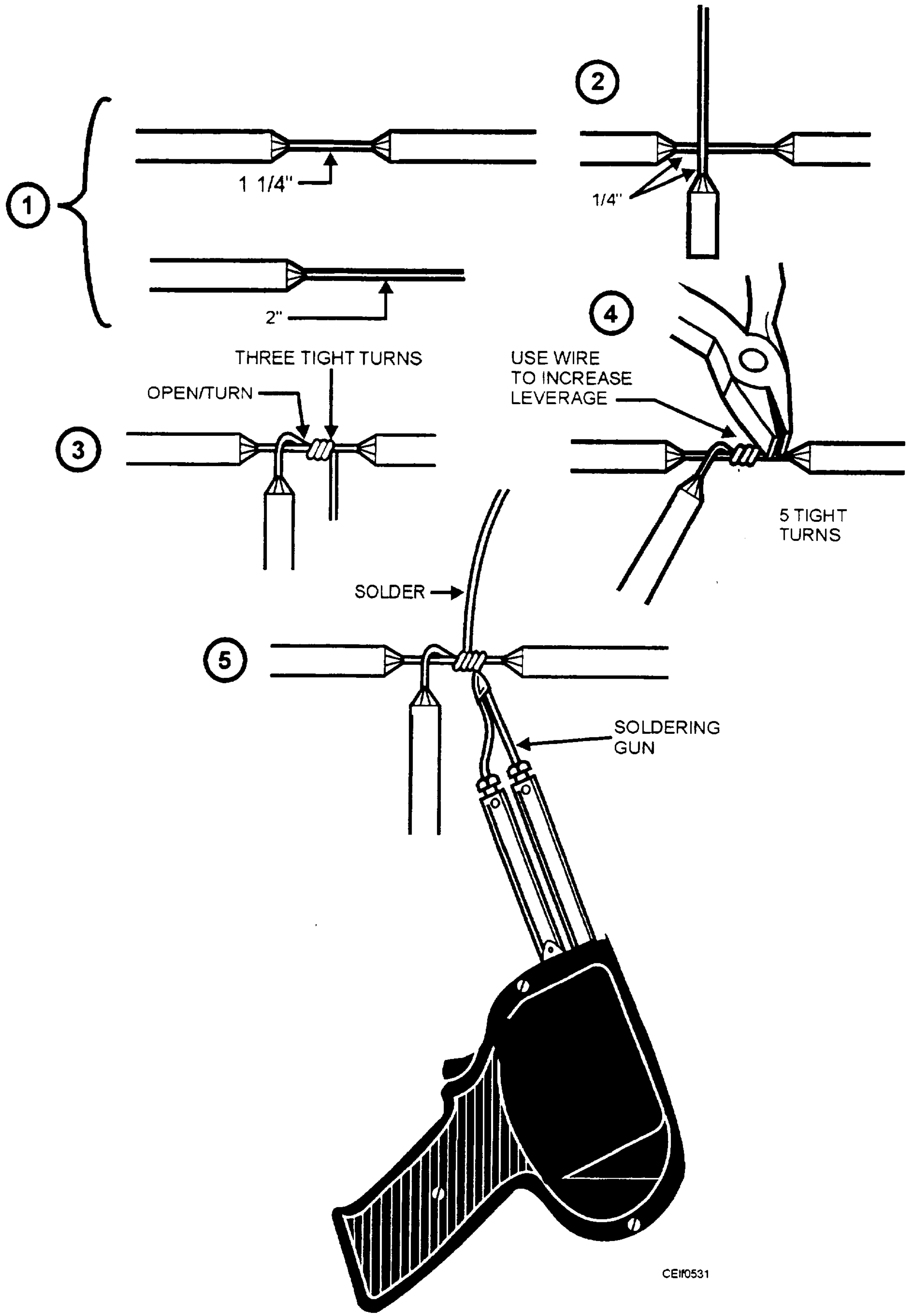


**Figure 5-31.—T-tap used to connect into an ongoing line.**

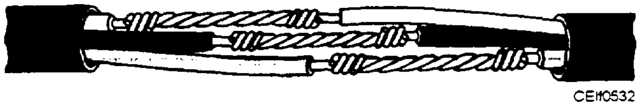


**Figure 5-32.—Portable cord splices.**

### Cable Splices

Large stranded cables (fig. 5-33) are not often used in residential wiring; however, they are used in other situations. such as for battery jumper cables and welding cables. When jumper cables or welding cables are broken, they can be temporarily repaired, as shown in figure 5-33.

### Soldering Splices

Because solderless connectors (such as plastic end caps) are time-saving and easy to use. the electrician no longer needs to solder each and every splice. It not only takes less time to make a solderless connection but also requires less skill. However. soldering is still the most reliable method of joining pieces of wire, and every electrician should learn how to solder.

Once the decision is made to solder an electrical splice and the insulation has been stripped off the wire, the splice should be soldered as soon as possible. The longer the splice is exposed to dirt and air. the more oxidation will occur thus lessening the chance of a good solder joint. Clean metal surfaces. free from oil. dirt. and rust (oxidation) are necessary to allow the melted solder to flow freely around the splice. The surfaces may be cleaned by using light sandpaper or an emery cloth or by applying flux to the joint as it is heated

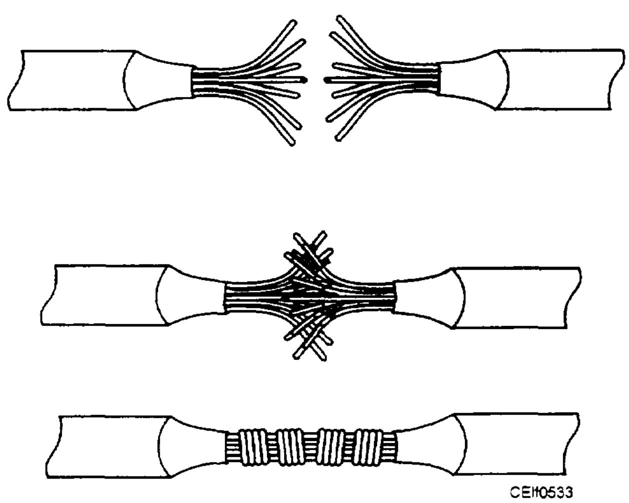


**Figure 5-33.—Gable splices.**

Solder usually comes in either bar or wire form and is melted with heat from soldering devices. such as a soldering iron. soldering gun. or propane torch (fig. 5-34).

The electric soldering iron and soldering gun are used when electrical service is available. The propane torch is used to solder large wires or when there is no electricity at the jobsite. Whatever method you use, be sure to apply solder on the side of the splice opposite the point where you apply the heat. Figure 5-35 shows the three methods of soldering. The melting solder will flow toward the source of heat. Thus, if the top of the wire is hot enough to melt the solder, the bottom of the wire closest to the heat source will draw the solder down through all the wires. Allow the splice to cool naturally without moving it. Do not blow on the joint or dip it in water to cool it. Rapid cooling will take all the strength out of a solder joint. Once it is cooled, clean off any excess flux with a damp rag, then dry and tape it.

**WARNING**

Avoid breathing the fumes and smoke from hot solder. Some solder contains lead which if inhaled or ingested can cause lead poisoning. Avoid prolonged skin contact with fluxes. Your supervisor will give you a Material Safety Data Sheet (MSDS) with the precautions for solder and flux.

### Taping Splices

Taping is required to protect the splice from oxidation (formation of rust) and to insulate against electrical shock. Taping should provide at least as much insulation and mechanical protection for the splice as the original covering. Although one wrap of plastic (vinyl) tape will provide insulation protection up to 600 volts, several wraps may be necessary to provide good mechanical protection.

When plastic tape is used, it should be stretched as it is applied. Stretching will secure the tape more firmly. Figures 5-36 through 5-39 show the most commonly used methods of taping splices.

## ELECTRICAL SAFETY

Safety for the electrician today is far more complicated than it was 20 years ago. But with proper use of today's safeguards and safety practices, working on electrical equipment can be safe. Electricity must be respected. With common sense and safe work practices, you can accomplish electrical work safely.

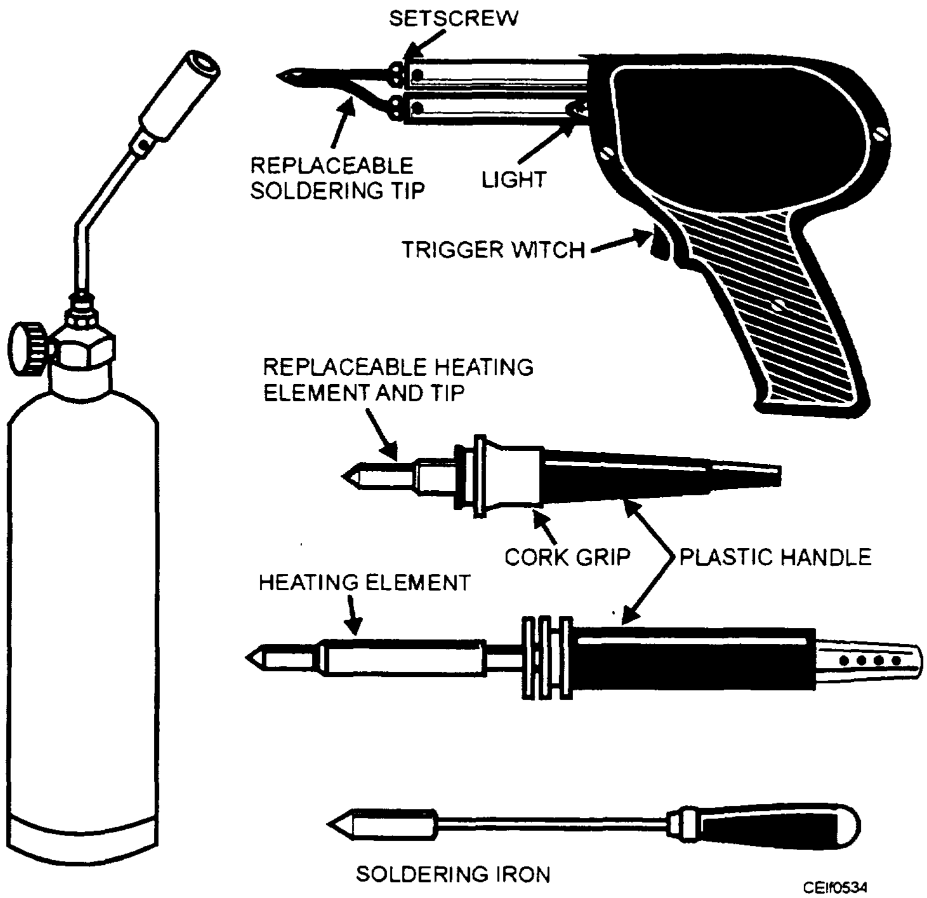


**Figure 5-34.—Sources of heat for soldering splices.**

An electrician must know and be able to apply the principles of electricity safely. If you disregard your own safety, you also disregard the safety of your fellow workers. Remember that the time to prevent an accident is before it happens. Respect for electricity comes from understanding electricity. Whenever in doubt, always ask your supervisor. Report any unsafe condition, unsafe equipment, or unsafe workpractices to your supervisor as soon as possible.

**FUSES**

Before removing any fuse from a circuit, be sure the switch for that circuit is open or disconnected. When removing fuses, use an approved type of fuse puller and break contact on the hot side of the circuit first. When replacing fuses, install the fuse first into the load side of the fuse clip, then into the line side.

**ELECTRICAL SHOCK**

Electrical shock occurs when a person comes in contact with two conductors of a circuit or when his or her body becomes part of the electrical circuit. In either case, a severe shock can cause the heart and lungs to stop functioning. Also, because of the heat produced by current flow, severe bums may occur where the current enters and exits the body.

Prevention is the best medicine for electrical shock. Respect all voltages and follow safe work procedures. Do not take chances. CEs, with the exception of very few personnel with special training, are not qualified to work on live circuits.

**PORTABLE ELECTRIC TOOLS**

When using portable electric tools, always make sure they are in a safe operating condition. Make sure there is a third wire on the plug for grounding in case of shorts. Theoretically, if electric power tools are grounded and if art insulation breakdown occurs, the fault current should flow through the third wire to ground instead of through the operator’s body to ground. Always use a ground-fault circuit-interrupter (GFCI) with portable electric tools. New power tools are double insulated eliminating the need for a ground prong; but for safety reasons, they still should be used with a GFCI.

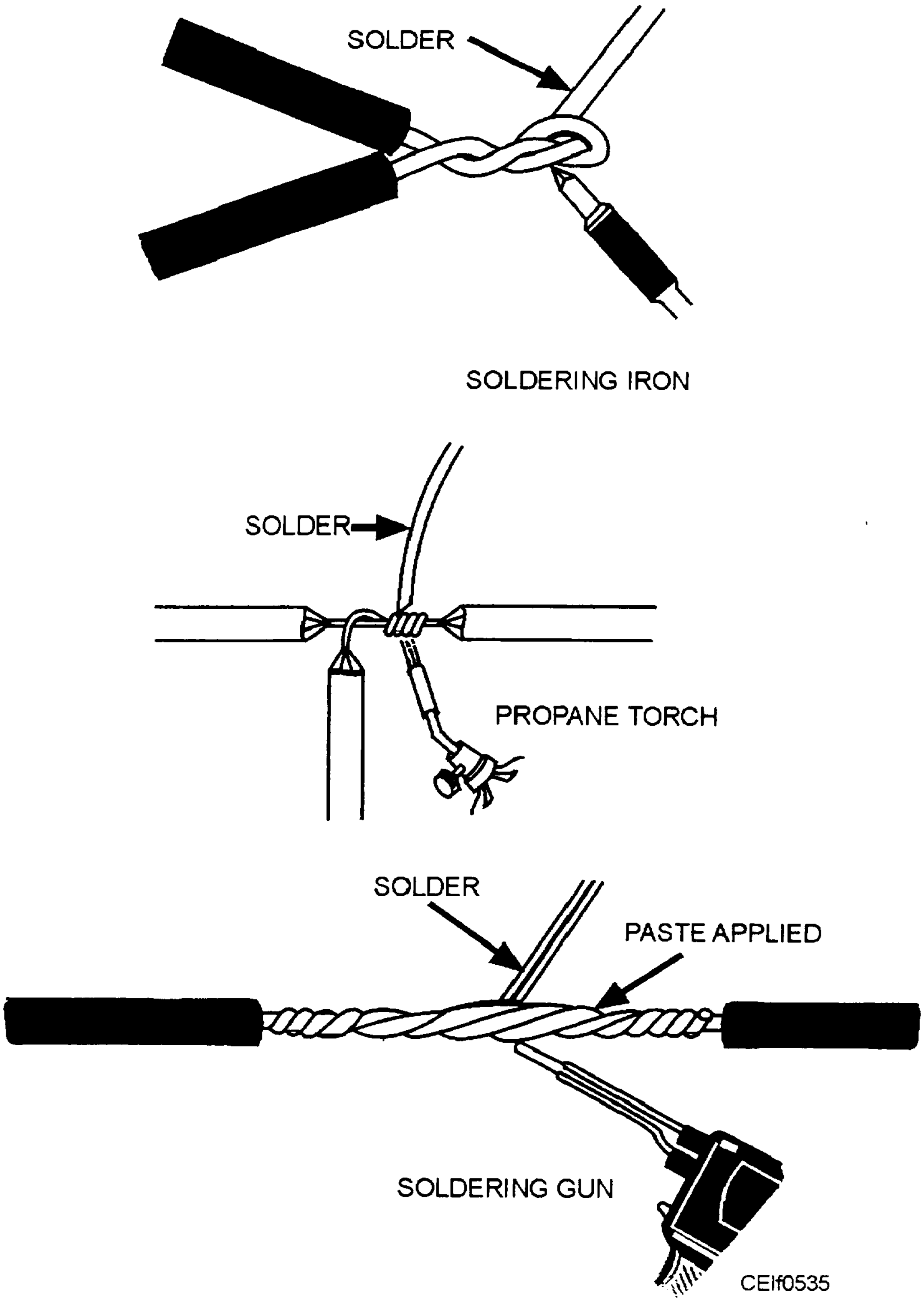


**Figure 5-35.—Three methods of heating a solder joint.**

## OUT-OF-SERVICE PROTECTION

Before any repair is to be performed on a piece of electrical equipment, be absolutely certain the source of electricity is open and tagged or locked out of service. Whenever you leave your job for any reason or whenever the job cannot be completed the same day. be sure the source of electricity is still open or disconnected when you return to continue the work. Seabees have died because they did not follow proper tag and lock-out procedures. These procedures are a must. It takes time to do it, but it is worth your life.

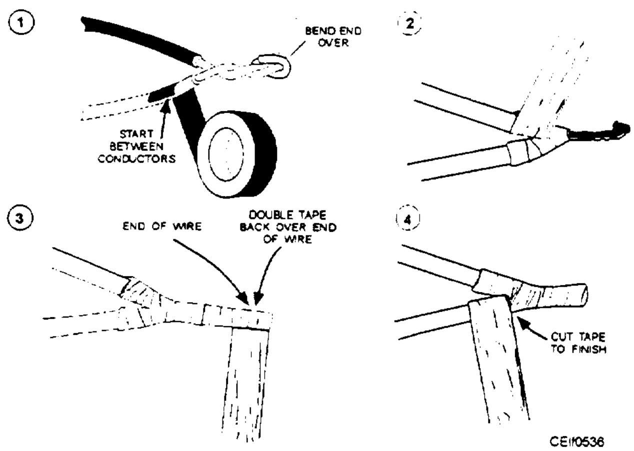


**Figure 5-36.—Technique for taping a pigtail splice.**

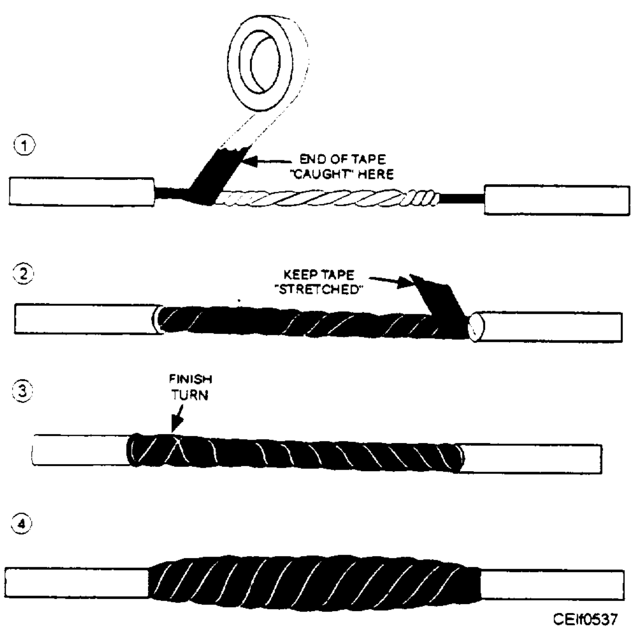


**Figure 5-37.—Technique for taping a Western Union splice.**

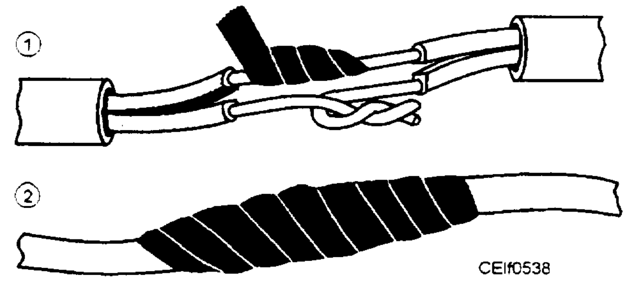


**Figure 5-38.—Technique for taping a cord splice in an emergency only.**

## SAFETY COLOR CODES

Federal law (OSHA) has established specific colors to designate certain cautions and dangers. Table 5-6 shows the accepted usage. Study these colors and become familiar with all of them.

## CLOTHING AND PERSONAL PROTECTIVE EQUIPMENT

As a crew leader. you must be familiar with required safety equipment and the conditions under which the equipment is to be used for your crew to perform an assigned task safely. The following is a list of common clothing and protective equipment requirements for working around electricity.

- Wear thick-soled work shoes for protection again sharp objects, such as nails. Wear work shoes with safety toes if the job requires.
- Wear electrically insulated gloves when there is the slightest chance that you might come in contact with energized parts.
- Wear rubber boots in damp locations.
- Wear safety goggles for protection against airborne particles, electrical sparks, and acid splashes.
- Wear a hard hat. Wear an approved safety helmet when on a project site. Be careful to avoid placing your head too near rotating machinery.
- Wear gloves when handling sharp objects.

## FIRE SAFETY

Fire safety should always be of great concern to you as a shop supervisor or leader. Furthermore, every member of your crew should be concerned with fire safety. The following fire safety information will help you prevent or combat fires.

The chances of fire may be greatly decreased by following rules of good housekeeping. Keep debris in a designated area away from the building. Report to your supervisor any accumulations of rubbish or unsafe conditions that are a fire hazard.

If a fire should occur, however, the first thing to do is give an alarm. All workers on the job should be alerted; the fire department should be called. In the time before the fire department arrives, a reasonable effort can be made to contain the fire. In the case of some smaller fires, portable fire extinguishers that should be available at the site can be used.

Table 5-6.—OSHA Safety Color Codes

| OSHA SAFETY COLOR CODES | |
|---|---|
| Red | Fire protection equipment and apparatus: portable containers of flammable liquids: emergency stop buttons; switches |
| Yellow | Caution and for marking physical hazards. waste containers for explosive or combustible materials; caution against starting. using. or moving equipment under repair: identification of the starting point or power source of machinery |
| Orange | Dangerous parts of machines; safety start buttons; the exposed parts (edges) of pulleys, gears, rollers. cutting devices. and power jaws |
| Purple | Radiation hazards |
| Green | Safety; location of first aid equipment (other than fire fighting equipment) |

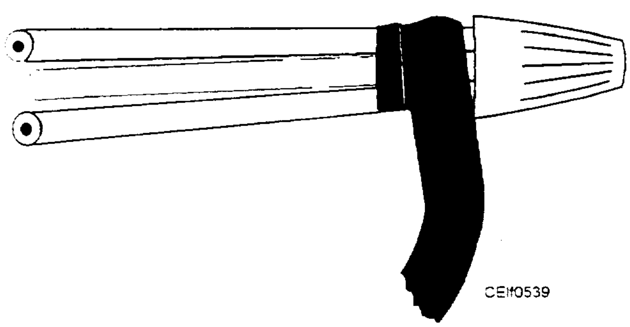


**Figure 5-39.—Technique for taping a solderless connector.**

The following list gives the four common types of fire. Each type of fire is designated by a class.

- Class A fires occur in wood. clothing, paper, rubbish, and other such items. This type of fire usually can be handled effectively with water. (Symbol: green triangle.)

- Class B fires occur with flammable liquids, such as gasoline, fuel oil, lube oil, grease, thinners, paints, and so forth. The agents required for extinguishing this type of fire are those that will dilute or eliminate the air by blanketing the surface of the tire. Foam. $CO_2$, and dry chemicals are used. but not water. (Symbol: red square.)

- Class C fires occur in electrical equipment and facilities. The extinguishing agent for this type of fire must be a nonconductor of electricity and provide a smothering effect. $CO_2$ and dry chemical extinguishers may be used, but not water. (Symbol: blue circle.)

- Class D fires occur in combustible metals. such as magnesium. potassium. powdered aluminum. zinc. sodium, titanium, zirconium, and lithium. The extinguishing agent for this type of fire must be a dry-powdered compound. The dry-powdered compound must create a smothering effect. (Symbol: yellow star.)

Figure 5-40 shows the symbols that are associated with the four classes. One or more of these symbols should appear on each extinguisher. Because all fire extinguishers cannot be used on all types of fires, the electrician should be aware of how to identify which fire extinguisher should be used.

Always read the operator's instructions before using an extinguisher. Also, never use water against electrical or chemical fires. Water also should not be used against gasoline, fuel, or paint fires, as it may have little effect and only spread the fire. Figure 5-41 shows some common fire extinguishers and their uses.

Fire extinguishers are normally red. If they are not red, they should have a red background so they can be easily located.

If the tire department is called, be ready to direct them to the fire. Also, inform them of any special problems or conditions that exist, such as downed electrical wires or leaks in gas lines.

In this chapter we have discussed various aspects of interior wiring (above and below grade), bending conduit. conduit support and installation. soldering and splicing, and electrical and fire safety. Each of these areas was briefly discussed and reference given to where you could find additional specific information. To understand the material discussed, you must study these references.

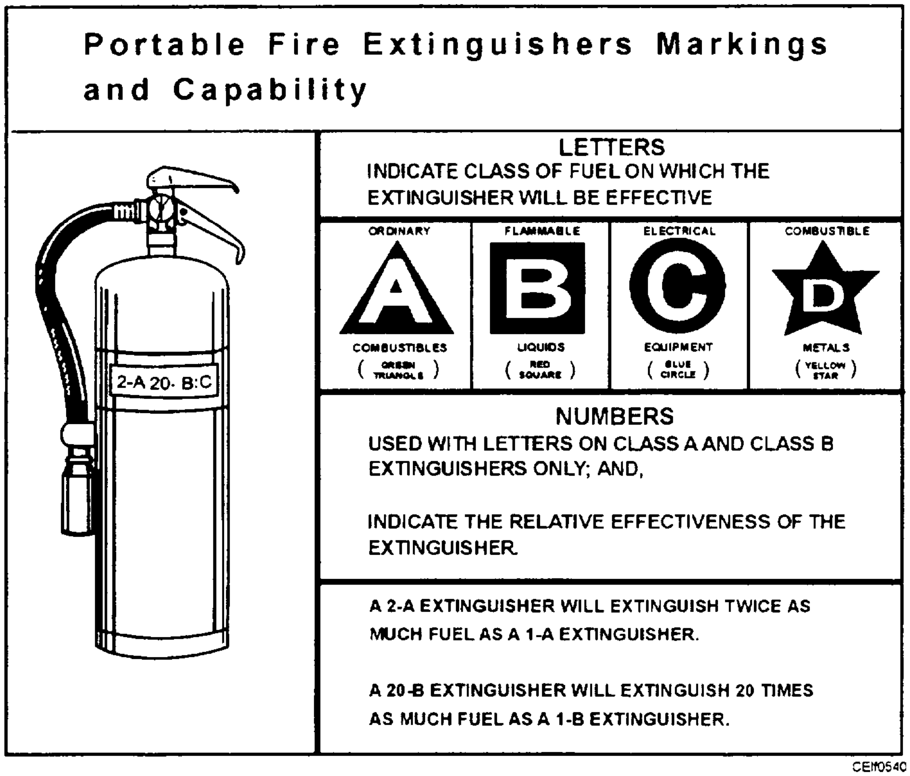


**Figure 5-40.—Fire extinguisher markings and capabilities.**

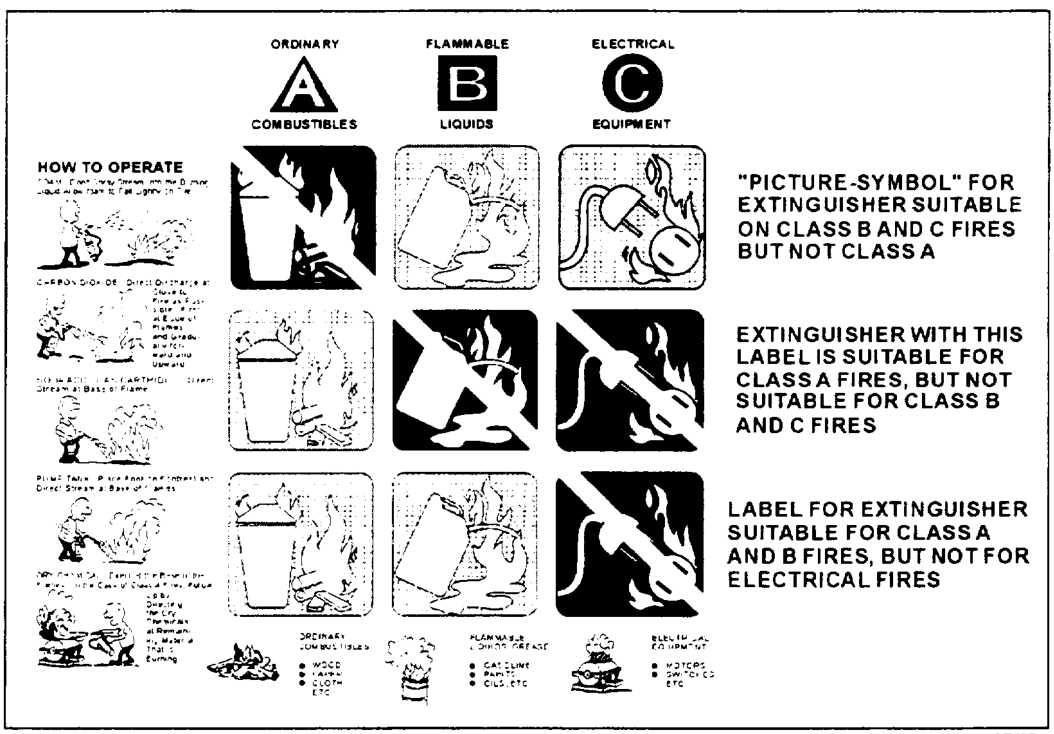


**Figure 5-41.—Selection of an effective and safe fire extinguisher.**

The following listed handbooks are excellent examples of references for further study.

- *Standard Handbook for Electrical Engineers* by Donald G. Fink and H. Wayne Beaty.
- *American Electrician's Handbook* by Terrell Croft and Wilford I. Summers.
- *National Electrical Code®* by the National Fire Protection Agency.